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project SEDAN

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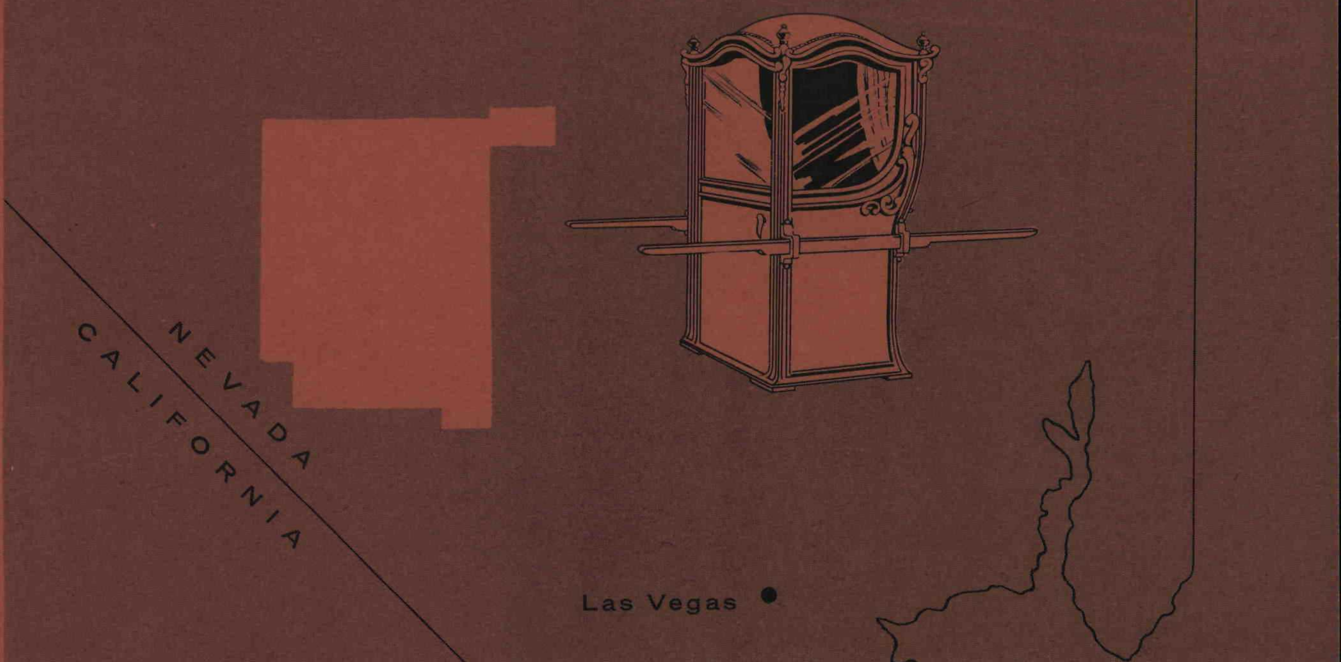

Part I. Characteristics of Fallout from a Deeply Buried Nuclear Detonation from 7 to 70 Miles from Ground Zero

Part II. Aerial Radiometric Survey

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PROJECT SEDAN

PROJECTS 62.86 & 62.80

PART I. CHARACTERISTICS OF FALLOUT FROM A DEEPLY BURIED NUCLEAR DETONATION FROM 7 to 70 MILES FROM GROUND ZERO.

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July 1966

ABSTRACT

Adequate samples of fallout from the detonation of a nuclear levice buried in desert alluvium at 635 feet below ground surface were obtained to delineate the eastern part of the fallout pattern from 7 to 70 miles from ground zero.

The distribution of radioactivity per unit area, mass per unit area, and mass per unit area per particle size fraction were determined. No correlation between radioactivity and mass was found.

The time of arrival of fallout and radiation intensity histories were recorded by field radiation detection instruments. Considerable differences occurred in time of arrival of fallout and its duration across the fallout pattern beyond 20 miles from ground zero.

Radioactive decay of samples from five laterals of the fallout pattern showed negative slopes of about 1.4 for the time interval from H + 48 to H + 600 hours.

Enough shear of the cloud occurred to permit a comparison of the isotopic fractionation existing above 10,000 feet MSL; but the data is limited to incomplete results from only five samples, one from each lateral, submitted to NRDL. The radiochemical analyses indicated a distance relationship and provided evidence of fractionation that substantiated a difference between the fallout debris from two levels of the cloud.

The data indicated that topography had a significant influence on the activity per unit mass, the particle size distribution and the fractionation of the fission product nuclides.

The Aerial Radiometric Surveys, CETO Project 62.80, determined the distribution of Sedan fallout to a distance of more than 200 miles from ground zero. The dose rate contours show the pattern to be asymmetric with a steep gradient west of the midline with a very gradual gradient on the east.

ACKNOWLEDGMENTS

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Special acknowledgment is due Mr. James J. Fuquay, Pacific Northwest Laboratories, Battelle Northwest, Richland, Washington. Mr. Fuquay was responsible for providing the liaison between the U. S. Weather Bureau Fallout Prediction Unit (FOPU) of the Test Manager's Organization and this Project, and for the interpretation of the data obtained by FOPU.

Appreciation is also extended to Dr. K. Z. Morgan, Chief, Health Physics Division, Oak Ridge National Laboratory, and to Messrs. Woodrow Cottrell, James C. Hart, Fred Napp, and James A. Worth of his staff who contributed materially to the success of this Project.

Acknowledgment is made with sincere regret of the untimely passing of Mr. Robert B. Guillou, Project Officer, Project 62.80.

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The objectives of this project were to determine certain physical and radiological characteristics of fallout from the detonation of a nuclear device buried in desert alluvium at 635 feet below ground surface. The area in which the fallout collections were made covered from 7 to 70 miles from ground zero, and the aerial radiometric survey extended the fallout distribution 130 miles. Specifically, the objectives were as follows:

(1) Delineate the fallout pattern to a distance at which the 1 mr/hr at H + 24 hour isodose contour can be defined and outlined. This was done through the coordinated efforts of CETO Project 62.80, the aerial radiometric survey, and this Project.

(2) Determine the distribution of radioactivity as a function of total gamma activity per unit area, mass per unit area, particle size per unit area, and mass per unit area per particle size fraction.

(3) Determine time of arrival of fallout along the pattern and the estimated duration of fallout and/or cloud passage.

(4) Measure the radioactive decay of samples from various locations in the pattern.

(5) Furnish selected samples to the Plowshare Division, Lawrence Radiation Laboratory (LRL), for radionuclide determinations.

1.2 BACKGROUND AND THEORY

Beginning with the first Environmental Radiation Survey (1947) of the fallout pattern from Shot Trinity, the Laboratory of Nuclear Medicine and Radiation Biology, School of Medicine, University of California (UCLA), Los Angeles has participated in off-site fallout programs in Operations Jangle (1951), Tumbler/Snapper (1952), Upshot/Knothole (1953), Teapot (1955), Plumbbob (1957) and Hardtack II (1958). Weapons Test Reports and other reports resulted from these studies (References 1, 2, 3, 4, 5,6,7, and 8).

Early studies indicated that before proper interpretation of the potential effects of fallout in a biosphere could realistically be made, the physical, chemical and radiological properties of radioactive debris needed to be determined and evaluated in terms of several environmental and biotic factors. For example, it was observed from annual studies, 1947-1951, along the fallout pattern from Shot Trinity (1945) in New Mexico, that the amount of residual gamma radiation along the fallout pattern was not an index of accumulated radionuclides in the indigenous mammals. The solubility of Trinitite and radioactive particulates was variable. Animals collected from near ground zero (<0.5 miles) did not indicate an accumulation of radionuclides above normal background. However, animals collected 21 miles from ground zero indicated some accumulation of radionuclides (References 1 and 2).

Some of the data and observations obtained from studies made at NTS from 1951 to 1959 were the following:

(1) The less-than 44 micron particle size fractions were the most significant in terms of biological accumulation via ingestion by mammals. Vegetation, including species of plants that made up the diets of the indigenous mammals collected as indicators of biological availability, retained predominantly the 10 to 20 micron fraction on their leaves (See References 9 and 10).

(2) Inhalation of fallout debris from tower-mounted detonations was not a significant pathway in the accumulation of I^{131} by rabbits and kangaroo rats within a 100 miles from ground zero in the fallout pattern (Reference 11).

(3) Gamma radiation as indicated by field measurements was not necessarily related to accumulation of Sr^{89} or Sr^{90} in the rabbits or kangaroo rats and mice collected along the fallout patterns from tower-mounted detonations. The maximum accumulation of Sr^{89} and Sr^{90} occurred in bone from rabbits collected at about 130 miles from NTS; the Sr^{89} was as much as five times more than the Sr^{90} six months after fallout (See References 9 and 12).

(4) Less than 0.06 percent of the total radioactivity deposited on the soil flats by Shot Jangle Underground (1951), beyond 10 miles from ground zero, was accumulated by the crop plants (radishes and clover) grown on the flats. It was predominantly Sr^{89} (References 9, 13 and 14). In contrast, a maximum of 0.008 percent of the radioactivity deposited at 48 miles from ground zero on the soil surface by a tower-mounted detonation was accumulated by red clover and only 0.001 percent was accumulated by the same crop from fallout

deposited at 7 miles from ground zero (Reference 14).

It was evident from these and other studies made by the field group of this Laboratory that for the different types of nuclear detonation, emphasis should be placed on the determination of the properties of the less-than 44 micron size fraction of fallout debris including its pattern of deposition in the biosphere, the degree of radionuclide fractionation at various times-of-fallout arrival, the chemical properties, and the size distribution within this fraction.

Predictions made available by LRL, for nuclear cratering experiments indicated that the type of nuclear device, its placement for detonation, the characteristics of the media at shot point, the prevailing wind directions and speeds at various levels of the "cloud" would influence the apparent characteristics of fallout debris collected along the resultant pattern. Comparison of some of the data obtained by the UCLA field group from Shots Jangle Surface (S) and Underground (U), beyond 10 miles from ground zero, illustrate some of these differences in characteristics of fallout. These differences were largely attributable to placement of the device. The S shot was about 2 feet above the soil surface whereas the U shot was buried 17 feet below the surface (Reference 3). (1) The average rate of decay of Shot S fallout debris collected at about 30 miles was significantly longer than for Shot U collected similarly. (2) Only glass-like beads were found in the Shot S debris, whereas the Shot U debris was irregularly shaped, very friable, dark

colored particles. (3) The radioactivity from Shot U debris was about 10 percent soluble in water and 38 percent soluble in 0.1N HCl; the solubility of Shot S particles was estimated to be less than 2 percent in 0.1N HCl. (4) Using standard mechanical size analysis methods for soil, it was found that 80 percent of the radioactivity was associated with the 75 to 150 micron soil fraction for the Shot S debris samples collected about 30 miles from ground zero while 40 to 50 percent of the radioactivity was associated with the less-than-44 micron soil fraction for Shot U debris (samples collected at 12 and 35 miles from ground zero).

These and other studies indicated that each different type of nuclear cratering experiment requires carefully designed and integrated fallout studies in order that comparable reference data be available for the prediction of the radiological safety of future engineering projects using nuclear devices. This Group's participation in the Sedan Event was intended, in part, to provide information which would indicate those studies and the methodology required for obtaining effective and reliable data on fallout from future cratering experiments.

CHAPTER 2

PROCEDURE

2.1 SHOT PARTICIPATION

This group conducted fallout studies from 7 to about 70 miles from ground zero on Shot Sedan. The extent of participation was contingent on a contractual agreement between the UCLA Laboratory and the U. S. Naval Radiological Defense Laboratory (NRDL), San Francisco to study fallout from Shot Small Boy, 18 miles to 200 miles from ground zero. Because of this commitment and the final scheduled "Ready Dates" of the two shots being on consecutive days, participation for Shot Sedan was limited to a maximum of 50 percent of the capability organized and set up by UCLA, CETO, and DOD for Shot Small Boy. Also, sample processing and radioactivity assays were done on a "non-interference" basis to Shot Small Boy. The Small Boy procedures and resultant data are reported in the combined NRDL/UCLA POR (Reference 15).

Shot Sedan was a nuclear device buried approximately 635 feet below ground surface, Area 10, Yucca Flat, the Nevada Test Site (NTS). Detonation occurred at 1000 hours PDT on 6 July, 1962.

2.2 ORGANIZATION

A total of 38 men participated in Project 62.86. Of these, 24 were USMC officers and men, 4 were civilians who were temporarily assigned from Health Physics Division, Oak Ridge National Laboratory, and 10 were from UCLA.

The personnel were divided into four operational units:

(1) The Field Group, consisting of 6 teams, was responsible for the placement of equipment, collection of samples, and radiation survey and field observations.

(2) The Laboratory Processing Group was responsible for the physical separation of the fallout material from the pellet matrix, the fractionation of the fallout material into various particle sizes, and the determination of the mass of the respective size fractions.

(3) The Radioactivity Assay Group was responsible for the radioassay of all the collected samples.

(4) The Administrative Group was responsible for the direction and necessary logistics and support.

A liaison was arranged and maintained with FOPU of the Test Manager's Organization to furnish this Project with current meteorological data and mid-line predictions. These data aided materially in the location of the fallout sampling and radiation detection equipment.

2.3 PROJECT OPERATION PROCEDURES

Mobile field teams, under the direction of the Project Control Center at Mercury, placed collecting and instrument stations before the estimated fallout arrival time along laterals which intersected the predicted fallout pattern at increasing distances from ground zero. The location of these stations was based on available pre-shot U. S. Weather Bureau meteorological data, the prediction of the mid-line of the pattern, and the degree of proficiency of the assigned field teams and their knowledge of roads or trails.

2.3.1 Placement of Stations

NTS and its adjacent environs in which this operation took place has been described in earlier reports (References 5,7 and 16).

During the Sedan operation, the area of study included distances up to about 70 miles generally northeast from ground zero, the direction of the predicted fallout pattern at the original H-hour, 0900 hours. Sampling stations were set up at 1.0 road-mile intervals along six laterals across the pattern. Mean distances of these laterals from ground zero were 12, 20, 32, 50, 60, and 70 miles.

Field teams were dispatched on D-1 day to various stand-by locations along the estimated fallout pattern. Communications were maintained by radio. Assignment of field teams to areas of greatest fallout probability and general coordination of a safe effort was accomplished with the support of a U. S. Air Force (USAF) C-47 radio-relay aircraft. Specific station assignments were given during the period between 9 hours before the original H-hour (0900) and up to 3 hours before the estimated time of fallout arrival at a particular lateral. The teams required from 3 to 5 hours for station placements depending on the team and their assigned lateral. Each team had a maximum capability of establishing 20 stations. In some cases, however, fewer stations were established along a lateral because of limitations of the roads and trails or changes in estimated time of fallout.

The equipment complement of each team that was placed at assigned locations is presented in Table 2.1. The instrumentation is described in Section 2.4.

Table 2.1 EQUIPMENT COMPLEMENT, FIELD TEAMS, AND ASSIGNED LOCATIONS RELATIVE TO GROUND ZERO

Team No.	T-11	T-10	T-9	T-8	T-7	T-12
Mean distance from GZ, miles	12	20	32	50	60	70
Granular Collectors (GC)	16	13	20	20	3	20
Time of Arrival Detectors (TOAD)	4	5	5	5	1	5
Gamma Intensity Time Recorders (GITR)	3	3	4	4	1	4
Radiacs	2	2	2	2	2	2

Approximately 9 hours after the detonation, field teams started recovery of their respective stations. All samples and field data were returned to the Project Laboratory at Mercury intermittently throughout D + 1 day.

2.3.2 Laboratory Operations

A laboratory had been established at Mercury by DOD and CETO/UCLA for the Small Boy fallout studies. These facilities were used on a "non-interference" basis for Shot Sedan. Fallout samples were processed and some characteristics of fallout debris were determined. A description of these procedures is presented in Section 2.4.3.

2.3.3 Aerial Radiometric Surveys

Activities of the Aerial Radiometric Surveys were integrated with these studies. The project utilized two aircraft operated by personnel from U. S. Geological Survey (ARMS I) and Edgerton, Germeshausen & Grier (ARMS II) to perform aerial radiometric surveys. ARMS I was associ-

ated with this Laboratory during operation Plumbbob (1957) and Hardtack II (1958). Pre-shot aerial background levels of radioactivity were determined along four laterals, approximately 60, 130, 180 and 260 miles from ground zero in the northern and eastern quadrants, the probable direction of fallout.

Beginning on D + 1 day and continuing through D + 3 days, flights were made to delineate the pattern and measure the levels of gamma activity at 500 feet above ground surface across the areas in which fallout occurred. See Part II of this report for details.

2.4 INSTRUMENTATION AND PROCEDURES

Procedures and instrumentation developed by this group during previous field operations were used as the basis for this study. These are described in detail in various reports (References 7, 9, 15, 16,and 17). Certain modifications were dictated by the experience on Shot Danny Boy (1962) that were incorporated in these studies for Shot Sedan. These are described in Section 2.4.3.

These instruments and procedures were selected to fulfill three objectives:

(1) collection of fallout material for subsequent characterization including determination of gamma activity per unit area, distribution of activity and mass of material according to particle size, and activity per unit mass per unit area;

(2) measurement of radiation, time-of-arrival and gamma field

decay along the pattern; and

(3) provision of suitable samples for radiochemistry by LRL and/or their contractors.

2.4.1 Fallout Collectors

Fallout debris was sampled by granular collectors (GC). Details of the GC assembly and associated processing procedures have been reported previously (References 15 and 17).

Briefly, the GC consisted of a flat metal tray (29 x 47 x 3/8 inch deep) divided into 2 sample areas (A + B) each 4.3 square feet. Each half of the tray was lined with a Mylar plastic sheet (E. I. Dupont Co.) folded to approximately fit the edges of the tray and held in place with "binder" clips. About 3.5 lbs. of 3/16 inch diameter plastic pellets (polyethylene), which provided a matrix to trap the fallout debris, were spread uniformly on each half of the plastic covered tray. All trays were placed on the ground surface as far from the influence of shrubs as possible and oriented with their long dimension parallel to the lateral.

When the trays were recovered, the Mylar sheets were gathered around the pellets making a package and tied. These individual packages were placed in Kraft paper bags, labelled and transported in cartons to the Mercury Laboratory for radio-assay and particle sizing.

2.4.2 Field Radiation Detection Instruments

Fallout-time-of-arrival detectors (TOAD) were placed at 25 selected stations to record only the time of fallout. Each of these units consisted of a Geiger tube coupled to a battery-powered clock

y a fuse assembly. The fuse assembly was designed to interrupt ıe circuit and stop the clock when a radiation intensity of 2 mr/hr as reached. More complete details of TOAD construction and peration have been reported elsewhere (Reference 18).

The time of arrival of the fallout was also measured by 19 ortable, battery-powered, gamma-intensity recording units (GITR). hese included seven portable remote-area monitors, (PRAM), (Jordan lectronics, Inc., Model 5) which have been described previously References 5 and 7), and 12 PRAM Model 6 units.

The PRAM Model 6, a modification of the PRAM Model 5, is a ortable radiation detection instrument with a self-contained ower supply. The weatherproof, shock mounted case houses a transis- orized amplifier, an Esterline-Angus recorder, and a battery ack capable of continuous operation in excess of 250 hours. The transistorized amplifier increases the strength of the signal from the Neher-White ion chamber and feeds the signal into the Esterline-Angus recorder.

The Neher-White ion chamber was modified at the suggestion of NRDL to minimize the effect of temperature. A thermistor and a 100-ohm potentiometer were added in parallel to the filament circuit of the ion-chamber electrometer tube. The potentiometer controlled the temperature amplitude and improved the linearity of the chamber.

Three ranges of sensitivity were selected for the GITR's used: 0.1 to 10 mr/hr, 0.1 to 10^4 mr/hr, and 10 to 10^4 mr/hr. Using the

NTS Rad Safe Co^{60} source and calibration range, multi-step calibration was carried out for each unit prior to location in the predicted fallout pattern by exposing the radiation detector to selected gamma-intensity levels throughout its particular sensitivity range. Recorded field readings were corrected using the calibration curve obtained for each instrument.

At the time of station recovery, the teams measured the gamma radiation intensity at each station. Two survey meters were used: OCDM No. CD-V700 (Anton Electronics Laboratory, Model 6) and the CY2312/PDR 27J (Chatham Electronics, Inc., Radiac) the latter furnished by the Marine Corps personnel assigned to this Project. These instruments also were calibrated prior to the survey using the NTS Rad Safe Co^{60} source and calibration range.

2.4.3 Laboratory Processing of Fallout

Initial measurements of gamma radiation were made on the GC samples while wrapped in the Mylar film with the NRDL end-on, low-geometry NaI scintillation counter (CH-1) with a 1 inch diameter by 1 inch thick crystal mounted in a shield that would accept 2 x 2 foot sample trays at distances up to 36 inches from the detector. This allowed the radioassay of very high levels of radioactivity (Reference 15 and 19). All samples recovered from the six laterals had levels of radioactivity sufficient to be assayed within acceptable limits of statistical variation for one minute counts. Counting efficiency was determimed using Cs^{137} standards which were prepared to approximate the configurations of the various samples assayed in

this unit. Based on these assays the samples were sorted into groups for processing, i. e. from low to high activity. All samples were separated into two fractions according to the following procedures.

The fallout debris from the GC's was recovered from the matrix (pellets) using the following procedure on each sample: 500 ml of isopropyl alcohol (IPA) was introduced into the Mylar plastic bag and the wet pellets were transferred to the washer. The washer assembly consisted of a screen 18 inches in diameter placed in a spring-mounted sieving pan actuated by an electric motor vibrator. The Mylar sheet that served as the bag was spread out and clipped to an upright stainless steel tray mounted over the rear of the screen. The Mylar sheet was then washed with a pressure spray of IPA, and a rubber squeegee was used to remove any adhering material from the sheet into the screen. Additional IPA was added to just cover the pellets.

A vibration-flow method of washing replaced the "dunking" procedure (Reference 17) used during previous test operations. The pellets were simultaneously stirred and subjected to mechanical vibration for one minute. Then, the IPA-fallout-debris-suspension was drained into a 6-liter enameled pot through a weighed 3-inch diameter, 44 micron sieve (U. S. No. 325) which retained all particles greater than 44 microns in diameter. An additional 500 ml of fresh IPA was sprayed over the pellets to displace the retained or adhering alcohol. Finally, all exposed surfaces of the apparatus were rinsed to remove any radioactive residua. A survey meter was used to check the complete-

ness of the final washing. If any activity was found, additional washing was done.

The material retained on the 44 micron sieve was washed with IPA again, the screen and its contents were dried under a heat lamp, weighed, and the gamma activity determined on the UCLA System. The UCLA-Scintillation System consisted of 2 x 2 inch NaI crystals affixed to photomultiplier tubes (Nuclear Chicago, Model 05-5) coupled to binary scalers (Nuclear Chicago, Model 183). The count acceptance rate of the scalers was increased one hundred fold by connecting two decade glow tubes (Atomic Instrument Co., Model 180) between the last scaling stage and the mechanical register of the scaler. The NaI detectors were mounted in standard cylindrical two-inch lead shields. Counting efficiencies were determined by Cs^{137} standards mounted in geometrical configurations similar to those of the experimental samples.

The $<44\mu$ material in the drain-pot was removed by filtering the IPA suspension through a weighed membrane filter (Millipore Filter Corp.). This residue was finally washed using IPA applied by a wash bottle, dried under the heat lamp, weighed, and the gamma activity of the sample determined on the UCLA System.

To check the degree of recovery initially, two hundred ml aliquots of the filtrate and 40 gram samples of the pellets were radio-assayed. Later, to expedite this step in the processing of the samples, the recovery was determined by re-counting the total pellet samples in the original Mylar bag.

In addition, selected samples from various locations were fractionated into 13 size groups as follows: the material retained by the 44 micron screen was quantitatively transferred to a stack of sieves or assembly containing weighed screens (1 5/8 inches O. D.) of the following mesh sizes: 1000, 500, 350, 297, 250, 210, 177, 149, 125, 105, 88, and 44 microns. This sieve assembly was then placed in a Ro-Tap (W. S. Tyler Co.) testing-sieve shaker and shaken for 30 minutes. After this, the assembly was dismantled, and the individual screens containing the respective size fractions of fallout material were placed in plastic petri dishes, weighed, and the gamma activity determined on the UCLA-Scintillation System. For additional details see References 15 and 17.

On selected samples, the $< 44\mu$ material on membrane filters was transferred quantitatively to 15 ml centrifuge tubes, and 10 ml of acetone was added to dissolve the filter. The suspension was stirred, centrifuged to separate the $> 2\ \mu$ from the $< 2\mu$ particles. The supernatant was decanted into a 2-inch diameter glass petri dish. This process was repeated twice.

The acetone remaining with the residue in the centrifuge tube was evaporated in a water bath. A small amount of IPA was added and used to transfer the residue to a weighed membrane filter which was dried, weighed and radioassayed.

2.5 CALCULATION OF RESULTS

2.5.1 Total Gamma Activity Per Unit Area

Samples from each station were counted using the NRDL CH-1 system.

The following calculations were made to obtain activity per square foot.

(1) The total number of counts observed on each sample was divided by the total time of counts (minutes) obtaining "observed counts per minute".

(2) These observed counts per minute were then corrected for the instrument background count rate and appropriate coincidence loss to give "net counts per minute". A coincidence correction was made on samples that had an observed count rate of 500,000 counts per minute or more.

(3) The net counts per minute were corrected to a common time using the decay rate experimentally determined on selected samples counted on the fifth shelf of the CH-1 system (Figure 2.1). A common time of H + 48 hours was used, because this was the earliest time of assay.

(4) Finally, the net counts per minute at H + 48 hours were corrected for sample geometry using a Cs^{137} reference source (2.50×10^{8} d/m) and area of collector surface to give disintegrations per minute per square foot. Disintegrations per minute per square foot values were divided by the respective mass per unit area to obtain the specific activity in disintegrations per minute per milligram.

2.5.2 Percent Activity and Mass Per Size Fraction

Using the UCLA-Scintillation System gamma activity was determined on the two groups of size-fractionated samples. The calculation of the percent activity and mass per size fraction was done as follows:

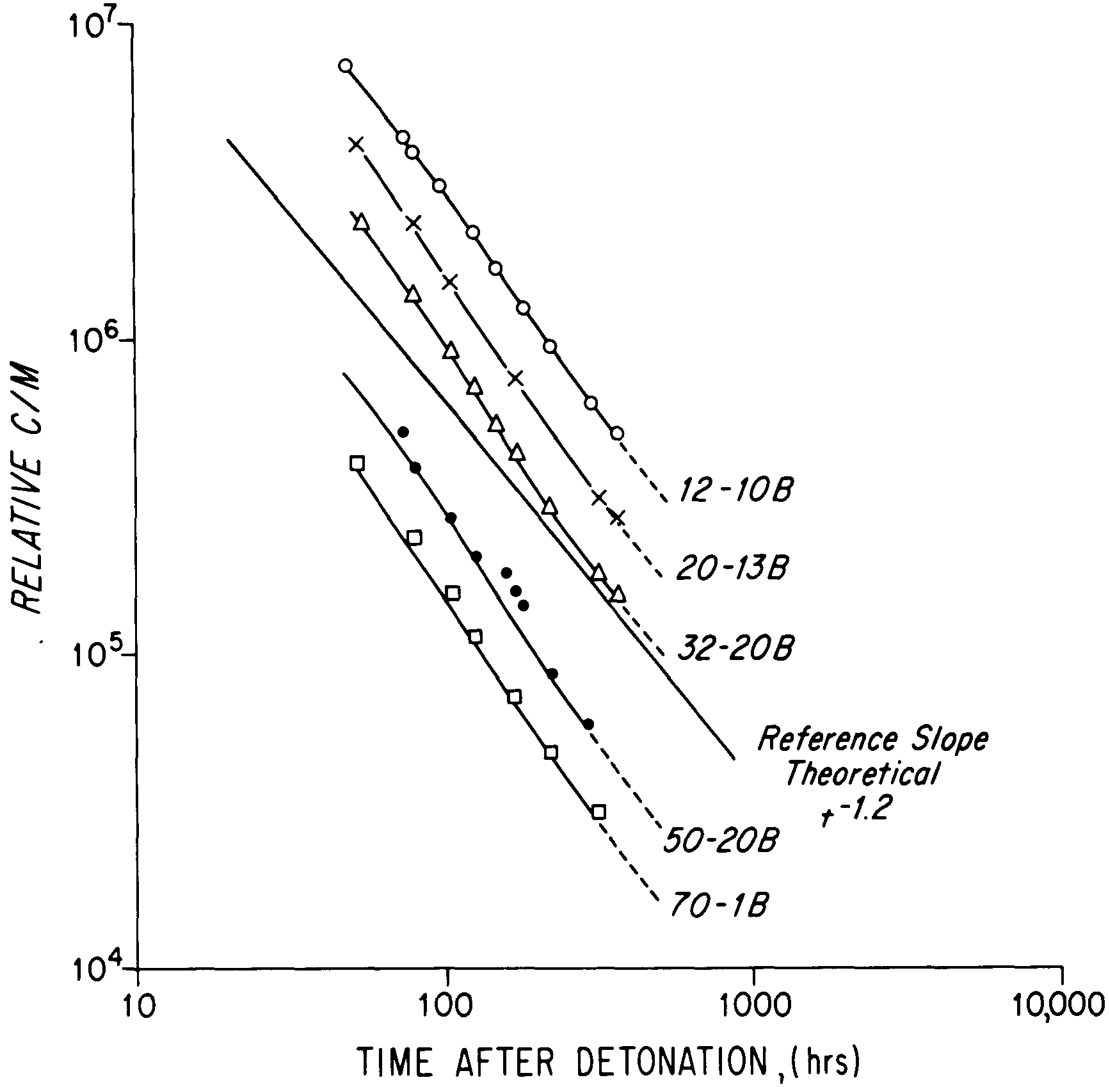

FIGURE 2.1 GAMMA DECAY CURVES DETERMINED ON CH-1 FOR SELECTED SAMPLES FROM EACH OF 5 LATERALS

(1) Net counts on these samples were obtained as described above in (1) and (2) Section 2.5.1 and corrected for sample geometry using an appropriate Cs^{137} reference source to give disintegrations per minute at time of assay. These disintegration rates for the samples were corrected to a common time using the average decay exponent of -1.32 calculated by Higgins (Reference 20) and measured by Lane (Reference 21).

(2) The sum of the activity in the 13 fractions and that remaining on the pellet matrix was the basis for calculating percentages. These percentages were converted to CH-1 equivalent activities at H + 48 hours by multiplying them by the CH-1 total activity per unit area (Item 4, Section 2.5.1). The resulting unit area activity was divided by the respective mass per unit area to obtain the specific activity per size fraction.

(3) Similar calculations were made on the $>44\mu$ and the $<44\mu$ samples with the percent based on the sum of the activity in those two size fractions and that remaining on the pellets.

2.6 RELIABILITY OF PROCEDURES

Procedures used in the characterization of fallout debris have various sources of error including those associated with fallout collection, laboratory processing, and radioassay of samples. An assessment of these errors is a measure of the reliability of the procedures.

Error associated with collection of fallout in the field included variation from such factors as the location of the trays

relative to vegetation and/or microterrain features, the techniques employed in the placement and recovery of the trays, and the micro-meteorological conditions existing in the sampling area. These conditions determine the amount of extraneous material, inert and/or radioactive, that is deposited on the GC tray with the fallout debris and hence the inherent error in the final result. Based on studies by the Environmental Assessments group of UCLA, one might expect 10 to 20 milligrams of debris per square foot per day in a pot collector (Reference 22), but with a GC tray on the soil surface, it would be reasonable to expect much higher values. Higher values may also be the result of wind velocity under certain conditions. It has been shown (Reference 23) that the amount of debris picked up by the wind is a function of the particle size, the quantity of each size fraction present, the shape of individual particles, the type of surface cover, the wind speed, the temperature, the humidity, and the amount of precipitation.

An estimate of the background values of the radioactivity and mass redistributed during a 24 hour period in the environs east of NTS was made during training and indoctrination of personnel for Shot Small Boy prior to Shot Sedan. A gamma radioactivity background of 1.64×10^4 c/m/ft^2 was established, for example, for a typical area north of St. George, Utah. This value was then used as a basis for estimating which samples had significant activity levels. A comparable value for mass was precluded by the variability between locations illustrated in Figure 2.2.

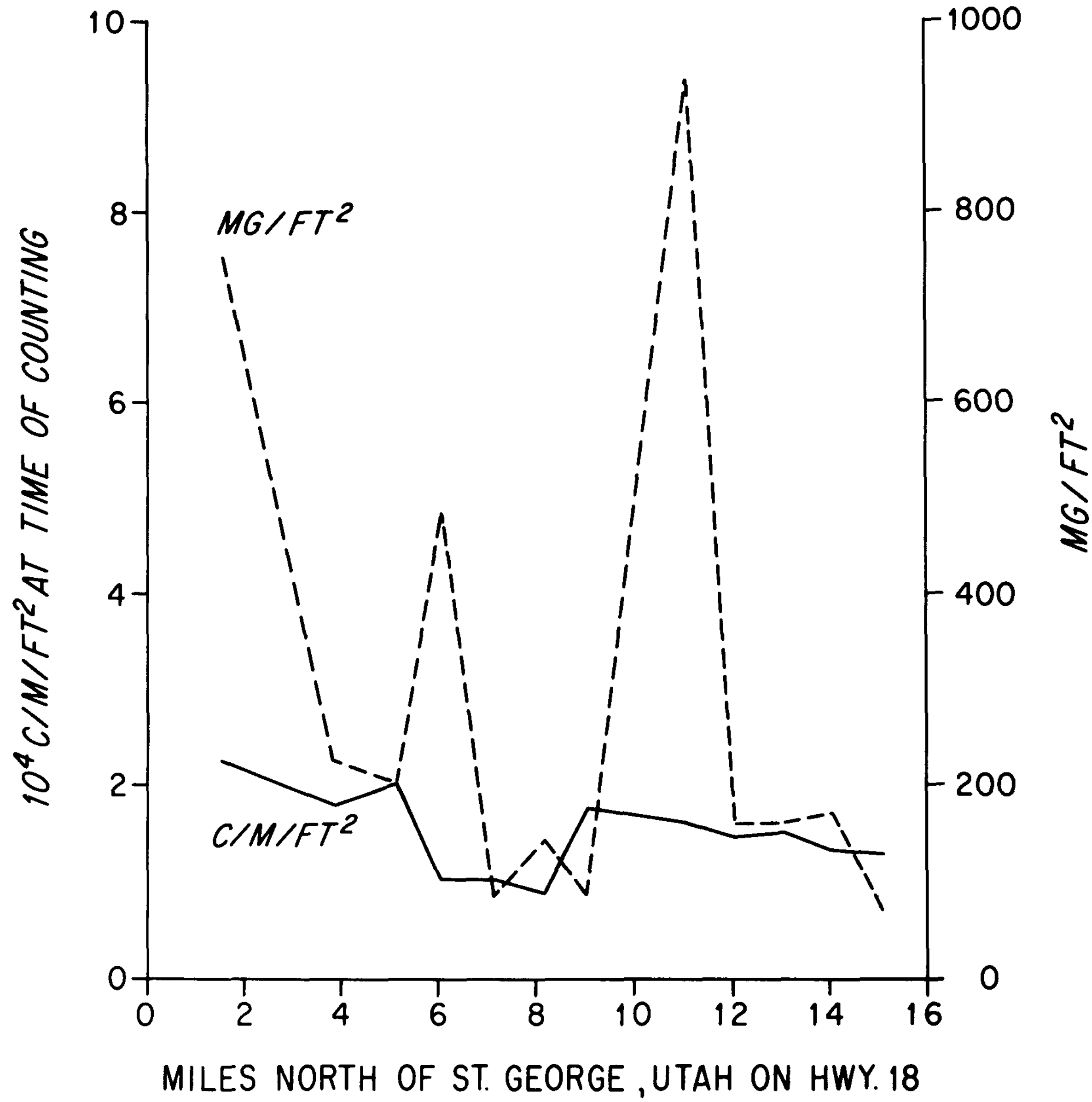

FIGURE 2.2 COLLECTION OF AMBIENT RADIOACTIVITY AND MASS BEFORE THE SEDAN EVENT, NORTH OF ST. GEORGE, UTAH ON HIGHWAY 18

A second category that introduced error was laboratory processing which included washing, wet and dry sieving, filtering, drying and weighing. Results obtained are indicated by the amount of activity and/or debris remaining on the pellet matrix which varied somewhat from one lateral to another with a range of means from 4 to 10 percent (See Table 2.2). Also, the mass determinations were made on Ainsworth Right-A-Way balances to the nearest tenth of a milligram. Of the material washed from the pellets an average of

Table 2.2 RADIOACTIVITY REMAINING ON PELLETS

Lateral	Number of Stations	Mean Percent*
12	7	9.6
20	5	6.2
32	8	8.8
50	9	8.8
70	11	4.3

* See Appendix Table A-4

93 percent of the activity and 96 percent of the mass were recovered in those samples that were separated into 13 size fractions. Tables 2.3 and 2.4 present these data.

The third category, assay of the individual size fractions, was done on the UCLA-Scintillation System with a maximum variation of plus or minus 10 percent, but the majority of the results were better than 5 percent. Counting techniques which include such items as

Table 2.3 RECOVERY OF RADIOACTIVITY IN SIZE FRACTIONATION

Sample No.	Summation of Activity: >44μ & <44μ Fractions	Summation of Activity: 13 Size Fractions	Percent Recovery
	10^3d/m/ft^2		
12- 6A	62.5	58.2	93.0
12-13A	17,620	18,570	105.0
20- 3B	402	242.	60.2
20- 4A	1,495	1,405	94.0
32- 6A	31.7	30.4	95.9
32-13A	674	668	99.1
32-16B	5,620	5,936	105.6
32-17B	10,950	12,638	115.0
50- 7A	295	143	48.5
50-12A	247	228	92.4
50-15A	352	317	90.1
50-17A	618	583	94.4
50-18B	702	674	96.0
70- 5B	2,100	1,995	95.1
70- 8A	137	130	94.8
70- 9A	482	474	98.4
70-10A	398	395	99.2
70-15A	42	40	95.2
70-18A	254	251	98.7

Mean Percent = 92.89 ± 14.8

Table 2.4 RECOVERY OF MASS IN SIZE FRACTIONATION

Sample No.	Summation of Mass: >44μ & <44μ Fractions	Summation of Mass: 13 Size Fractions	Percent Recovery
	Mass, mg/ft^2		
12- 6A	137	141	103.0
12-13A	2,154	2,179	101.0
20- 3B	292	287	98.2
20- 4A	371	348	94.0
32- 6A	108	107	99.0
32-13A	378	364	96.2
32-16B	1,041	1,027	98.7
32-17B	1,365	1,339	98.0
50- 7A	298	286	96.0
50-12A	235	212	90.3
50-15A	317	306	96.5
50-17A	256	258	101.0
50-18B	372	347	93.3
70- 5B	19	18	94.7
70- 8A	86	75	87.2
70- 9A	247	256	103.0
70-10A	112	104	92.8
70-15A	48	42	87.5
70-18A	38	34	89.5

Mean Percent = 95.78 $\pm$ 23.3

position of sample under the detector, distance from the detector, and effect of sample configuration on geometry presented no serious problem within the UCLA system. An attempt was made to inter-calibrate the UCLA and the CH-1 systems by counting Cs^{137} sources of known activity at various distances on the several sensing devices. The factors obtained gave good results with Cs samples, but appeared to give variable results with Sedan samples. There were appreciable ratio differences between Sedan samples from two laterals counted on all five shelves of the CH-1, one at H + 150 hours and the other at H + 239 hours. These results indicated that more data was necessary to inter-calibrate the two systems. Therefore, in order to express all the values in comparable terms, the percentages of the particle size fractions were converted to CH-1 equivalent values as described in Section 2.5.2.

In summary then, if one considers 7 percent as an average value of the activity remaining on the pellet matrix and another 7 to 8 percent as representing general errors including counting, then one might reasonably expect an overall reliability of 85 percent for the activity determinations. A value of about 80 percent might be a better estimate for mass determinations.

CHAPTER 3

RESULTS AND DISCUSSION

All of the 92 established stations collected fallout debris from Shot Sedan. Table 2.1 (Chapter 2) shows the type and number of instruments and collectors placed along the laterals in the predicted fallout pattern from 7 to approximately 70 miles from ground zero.

3.1 FALLOUT PREDICTION, FALLOUT PATTERN & LOCATION OF STATIONS

Several factors determined the placement of stations along the predicted fallout pattern, such as: (a) confidence in the forecast wind direction and speed of the cloud for the period from H hour to H + 4 hours (Meteorological information was supplied by the Staff of Weather Forecasters and Fallout Prediction Unit, U. S. Weather Bureau, Test Manager's Organization); (b) the estimated time of arrival of fallout at the several trails and roads that could be used in placement of collecting stations along the predicted pattern; (c) the number of available teams and their knowledge of the terrain and the condition of the roads that could be used for station placement; (d) the efficiency of the personnel in setting up assigned stations; and (e) maintenance of a maximum operational capability in terms of personnel and equipment for Shot Small Boy scheduled to occur 24 hours later. For these reasons, only six of the twelve teams assigned to Shot Small Boy were sent to locations for Shot Sedan.

3.1.1 Pre-Shot Fallout Prediction and Station Location

Table 3.1 shows the wind structure forecast for 0900 hours

Table 3.1 **WIND STRUCTURE FORECAST FOR 0900 HOURS PDT, 6 JULY 1962, AND AS DETERMINED AT 1013 HOURS BY RADAR SOUNDINGS AT LOCATION BJY, YUCCA FLAT, SHOT SEDAN**

Readings given as bearing of origin and speed

Altitude	Forecast	Observed	
Ft above MSL	Degrees/knots	Degrees/knots	(mph)
20,000	230/25	---/--	
19,000*	---/--	250/06	(7)
18,000	220/25	220/06	(7)
17,000	---/--	200/06	(7)
16,000	220/20	180/16	(18)
15,000	---/--	190/13	(15)
14,000	210/20	190/17	(20)
13,000	---/--	190/33	(38)
12,000	215/15	200/26	(30)
11,000	---/--	200/20	(23)
10,000	200/15	210/16	(18)
9,000	200/15	220/13	(15)
8,000	200/15	220/11	(13)
7,000**	200/15	200/09	(10)
6,000	190/10	170/09	(10)
5,000	190/10	150/11	(13)
Surface (4317)	180/08	160/10	(11)

* Estimated top of cloud

** Elevation of Oak Springs Butte, about 4 miles north of GZ

Pacific Daylight Time (PDT), the originally scheduled H hour. Also, the table shows the observed wind direction and speed in Yucca Flat 13 minutes after the actual H hour, 1000 hours. The estimated fallout time, the prediction of the bearing of the mid-line of the pattern, and the estimated radiation dose at several distances from ground zero were based on the forecast winds four to eight hours before the actual H hour. Also, these predictions were based on an estimated cloud height of 10,000 feet MSL, approximately 9,000 feet lower than the observed cloud height. Using procedures for station location outlined in Section 2.3.1, all collecting stations were established on the basis of a predicted mid-line having a bearing of 25 degres. However, the bearing of the measured mid-line was 5 degrees (Reference 24 and Part II of this report.) This difference of 20 degrees was due to changes in both wind direction and speed at some elevations of the cloud because of the one hour delay in detonation and the increased height of the cloud. These changes could not be accommodated in the time available. For a detailed analysis of these changes, see the final report by the Fallout Prediction Unit, Reference 24.

3.1.2 Fallout Pattern Characteristics

A composite of data, obtained by aerial radiometric survey (CETO Project 62.80, Part II of this report), by a ground radiation survey (OFF-SITE Rad-Safe Group, Reference 25), by surveys made by this project, and by measurements of activity collected on the fallout collectors, was used to delineate the fallout pattern. Mr/hr values

at H + 24 hours based on ground survey readings along the roads and trails at 3 feet above the soil surface and converted 500 foot aerial survey measurements were plotted as a function of distance from ground zero. Points of equal intensity were connected by dose rate contour lines. The resulting isopleth, Figure 3.1, shows the area of distribution of the radioactive debris out to a distance of more than 70 miles. It is apparent that the difference of 20 degrees accounts in part for the location of all stations to the right, or east, of the mid-line.

The isopleth also shows a spreading of the eastern part of the fallout pattern with increase in distance from ground zero. The unit area activity values appear to decrease at a normal rate along the laterals with increased distance from the midline, but an examination of the activity per unit mass indicates that the mass varies considerably from one part of a lateral to another. The following explanation is suggested for this phenomenon. If it is assumed that the direction and speed of the observed winds measured in Yucca Flat persisted at more than 50 miles from ground zero, the cloud layer between 11,000 to 15,000 feet MSL travelled through this area on a bearing of 10 to 20 degrees at speeds from 23 to 38 miles per hour (20 to 33 knots). The cloud layers above and below this higher speed layer travelled at slower speeds and in different directions as indicated by the times of arrival recorded at stations on laterals 32 and 70 (See Sectin 3.2.1). The possibility existed, therefore, that two different sources of fallout, i. e., base surge

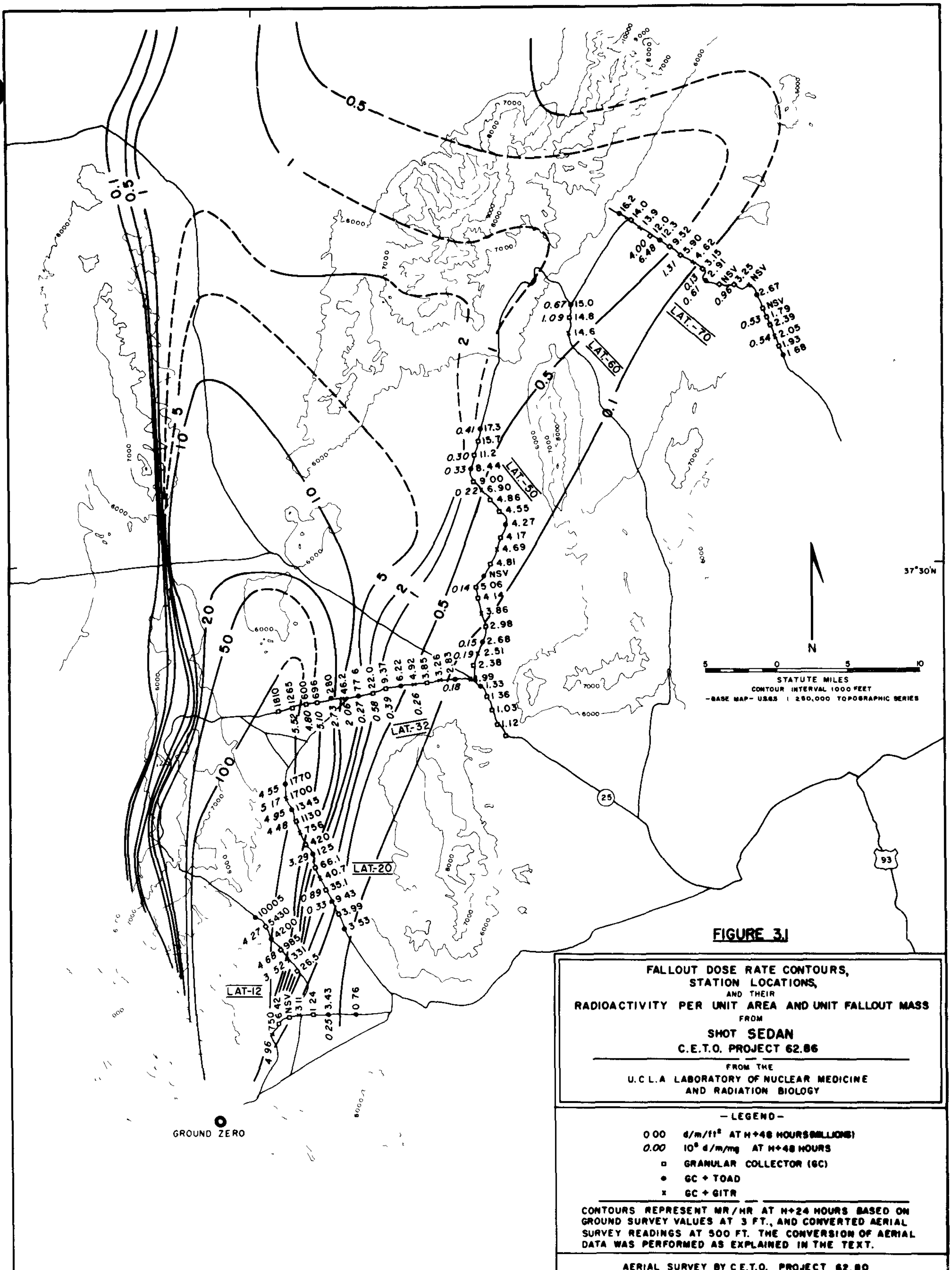

FIGURE 3.1

FALLOUT DOSE RATE CONTOURS,
STATION LOCATIONS,
AND THEIR
RADIOACTIVITY PER UNIT AREA AND UNIT FALLOUT MASS
FROM
SHOT SEDAN
C.E.T.O. PROJECT 62.86
FROM THE
U.C.L.A LABORATORY OF NUCLEAR MEDICINE
AND RADIATION BIOLOGY

— LEGEND —

0.00 $d/m/ft^2$ AT H+48 HOURS (MILLIONS)
0.00 10^6 d/m/mg AT H+48 HOURS
□ GRANULAR COLLECTOR (GC)
• GC + TOAD
x GC + GITR

CONTOURS REPRESENT MR/HR AT H+24 HOURS BASED ON GROUND SURVEY VALUES AT 3 FT., AND CONVERTED AERIAL SURVEY READINGS AT 500 FT. THE CONVERSION OF AERIAL DATA WAS PERFORMED AS EXPLAINED IN THE TEXT.

AERIAL SURVEY BY C.E.T.O. PROJECT 62.80
GROUND SURVEY BY C.E.T.O. PROJECT 62.86

and/or throwout material, and the remaining portion of the cloud above 10,000 feet MSL, contributed to the fallout.

On this basis, the western stations on lateral 70, located on and near the eastern slope of the Quinn Canyon Range, should have collected fallout debris that was from above the throw-out portion of the cloud. The data indicate that there was some overlapping on the western stations of that lateral, but fallout debris from above the throw-out portion of the cloud did occur to the east of station 7. Fallout along the western stations of each lateral was primarily base surge and/or throw-out.

3.2 MEASUREMENTS OF RADIATION ARRIVAL AT STATION LOCATIONS, DURATION OF DEPOSITION OF FALLOUT AND APPARENT FIELD DECAY

Radiation intensity measurements made during a period of the time a cloud travels over and through an area may assist in the interpretation of the phenomenon of deposition and in the identification of certain properties of the debris. With optimum conditions, it is possible to identify and estimate such items as: (a) time of arrival of radiation at the instruments' location; (b) duration of cloud passage and fallout deposition; (c) radiation intensity and dose due to passage of the fallout cloud; (d) apparent rate of radiation decay in the environment after fallout deposition; (e) amount of secondary deposition, or removal, of radioactive debris at a location; and (f) radiation dosage due to fallout and cloud passage during the period from the time of arrival of radiation to the time of station recovery.

The two types of instruments used for these measurements have been described in Section 2.4.2. The TOAD registered only the time at which gamma radiation intensity reached 2 mr/hr at the ground surface. The other instrument, GITR, provided a continuous record of radiation intensity at approximately 3 feet above the ground surface. Most of the GITR's were adjusted to record a minimum intensity of 0.1 mr/hr. A few units were adjusted to record a minimum intensity of 10 mr/hr, and these were located at stations predicted to receive higher dose rates.

3.2.1 Time of Arrival of Radiation and Duration of Cloud Passage or Deposition

Figure 3.2 shows the recorded time of arrival of radiation and the duration of cloud passage and fallout at the stations at which the instruments were located. Frequently the initial maximum intensity was followed by secondary increases of radiation suggesting additional radioactive debris was deposited or remained suspended in the environs of the GITR. In several locations, the typical maximum followed by the decay of radiation was not recorded; there was only a continuous increase of radiation.

The estimates of time of arrival were made by plotting radiation intensity (mr/hr) versus time (H + hrs). For estimates of duration of radiation or fallout and secondary deposition or removal of debris in an area, these intensity readings were corrected to a common time (H + 24 hrs) by appropriate decay factors and plotted, mr/hr at H + 24

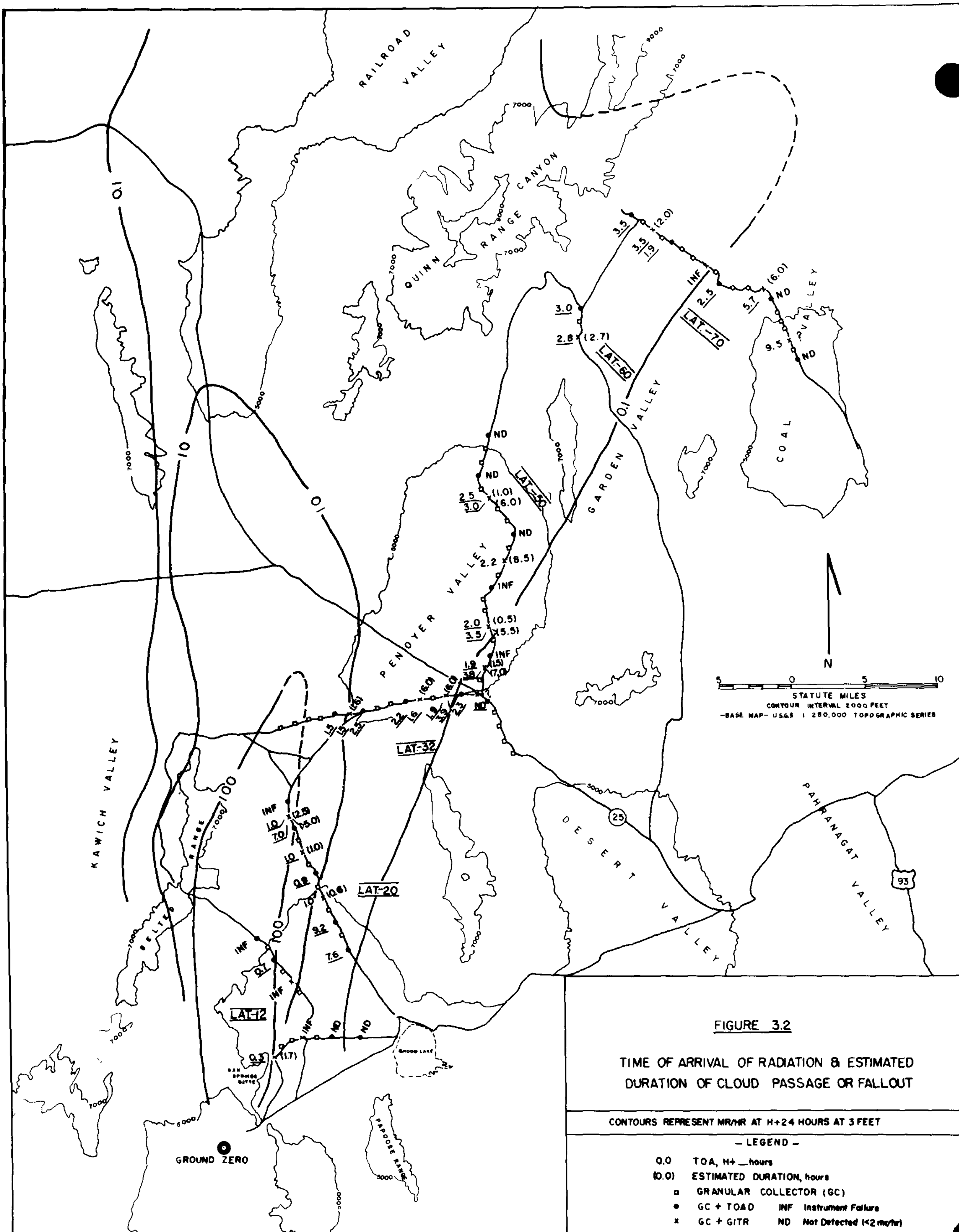

FIGURE 3.2

TIME OF ARRIVAL OF RADIATION & ESTIMATED DURATION OF CLOUD PASSAGE OR FALLOUT

CONTOURS REPRESENT MR/HR AT H+24 HOURS AT 3 FEET

– LEGEND –

0.0	TOA, H+ __ hours		
(0.0)	ESTIMATED DURATION, hours		
▫	GRANULAR COLLECTOR (GC)		
•	GC + TOAD	INF	Instrument Failure
x	GC + GITR	ND	Not Detected (<2 mr/hr)

hrs versus time. This permitted the resolution of the following queries: (a) was the initial radiation increase and maximum intensity due to cloud passage with minimal fallout; or (b) was the increase in radiation intensity due to the radioactive cloud's passing through the station location and from fallout; or (c) was radiation due predominantly to fallout? Table 3.2 presents an evaluation and interpretation of the GITR data.

The time of arrival of radiation across a lateral was predicted to vary several hours because of the observed wind shears and cloud height. The observed higher wind speeds of 20 to 33 knots at 11,000 to 15,000 feet MSL, travelling on an average bearing of 14 degrees with a shear of 10 degrees, probably resulted in the earliest measured time of arrival at stations beyond 15 miles from ground zero and after H + 1 hour. See Table 3.2 for data at stations 32-15, 32-16 and 70-5.

The cloud layers below 10,000 feet MSL had slower speeds, 9 to 16 knots, and a maximum horizontal shear of about 70 degrees (from 30 degrees west of north to 40 degrees east of north). The deposition of fallout from these layers was no doubt further complicated by the terrain over which it occurred. For example, the Oak Springs Butte complex is 3 to 5 miles from ground zero, and is oriented perpendicular to the direction of cloud travel. It has a maximum elevation of 7000 feet. Beyond this butte is the Belted Mountain Range. This range is nearly parallel to the path of the lower cloud and varies in elevation from 6000 to 8000 feet in a distance of 28 miles from ground zero.

Table 3.2 TIME OF ARRIVAL AND ESTIMATED DURATION OF FALLOUT AND/OR RADIATION FROM CLOUD PASSAGE AT GITR LOCATIONS ALONG THE PATTERN

INF, Instrument Failure; ND, radiation intensity not detectable at instrument setting; V, variable; K,1000

Station No.	Station Location: Distance from GZ, Miles	Station Location: Bearing from GZ, Degrees	Characteristics of Instrument: Range, mr/hr	Characteristics of Instrument: No. of Decades	Time of Radiation Arrival, H + hrs	Duration of Fallout and/or Cloud Passage Est in hours
12-1	7.2	030	10-10K	3 (GU)	0.3	2.6
	Note: At this station one maximum intensity period occurred from H + 0.4 to H + 2 hours. It was indicated that a clearing occurred from H + 2 to H + 5 hours. There is a suggestion that additional material came into this location and continued until H + 9.9 hours (Recovery time).					
12-4	9.5	038			INF	--
12-6	11.0	047	0	0 (T)	ND	--
12-8	12.5	053	0	0 (T)	ND	--
12-10	14.7	010	0	0 (T)	INF	--
12-12	13.5	015	0	0 (T)	0.7	--
12-14	12.5	023		(GU)	INF	--
20-1	16.4	032	0	0 (T)	7.6	--
20-3	17.5	027	0	0 (T)	9.2	--
20-5	18.7	023	10-10K	3 (GU)	1.0	0.6
20-7	20.0	019	0	0 (T)	0.9	--
20-9	21.4	016	10-10K	3 (GU)	1.0	1.0

Note: Only one maximum period at this station; primarily fallout with minor amount of radiation from cloud passage.

Table 3.2 TIME OF ARRIVAL AND ESTIMATED DURATION OF FALLOUT AND/OR RADIATION FROM CLOUD PASSAGE AT GITR LOCATIONS ALONG THE PATTERN(CONTINUED)

Station No.	Station Location: Distance from GZ, Miles	Station Location: Bearing from GZ, Degrees	Characteristics of Instruments: Range, mr/hr	Characteristics of Instruments: No. of Decades	Time of Radiation Arrival, H + hrs	Duration of Fallout and/or Cloud Passage Est in hours
20-11	22.8	013	0	0 (T)	1.1	--
20-12	**23.5**	**012**	0.1-10K	5 (GU)	1.0	2.5
					7.0	> 5.0
Note:	First maximum due to both cloud and fallout at this station; the second period of >5.0 hrs was a significant steady increase continuing from H + 7 hrs to station recovery; probably due to debris transported through station area by wind or drainage flow.					
20-13	24.6	011	0	0 (T)	INF	--
32- 5	36.4	031	0	0 (T)	ND	--
32- 6	36.4	029		(GU)	V	
32- 7	35.9	028	0	0 (T)	2.3	--
32- 8	35.4	027	0.1-10	2 (GU)	V (1,9,3,9)	6
32-10	34.3	024	0.1-10K	5 (GU)	V (1.6)	6
Note:	Recorded radiation at stations 32-8 and 32-10 indicated several 2 to 5 fold five minute maximums beginning at H + 1.9 hrs with a net increase in residual radiation intensity continuing until H + 10 hrs.					
32-11	33.8	023	0	0 (T)	2.2	--
32-14	32.0	018	0	0 (T)	2.5	--
32-15	31.7	016	0.1-10K	5	1.5	1.6
Note:	Station 32-15 recorded only one maximum period probably due to cloud passage and fallout.					
32-16	31.2	015	0	0 (T)	1.5	--

Table 3.2 TIME OF ARRIVAL AND ESTIMATED DURATION OF FALLOUT AND/OR RADIATION FROM CLOUD PASSAGE AT GITR LOCATIONS ALONG THE PATTERN (CONTINUED)

Station No.	Station Location: Distance from GZ, Miles	Station Location: Bearing from GZ, Degrees	Characteristics of Instruments: Range mr/hr	Characteristics of Instruments: No. of Decades	Time of Radiation Arrival, H + hrs	Duration of Fallout and/or Cloud Passage Est in hours
50- 2	38.3	028	0.1-10K	5 (GU)	1.9	1.5
					3.8	7.0
Note:	Sta 50-2 had two periods; the first was primarily radiation from cloud passage with a minor amount of fallout, the second period was a continuous increase of radiation presumably from fallout, from H + 3.2 hrs to station recovery at H + 10.5 hrs.					
50- 3	39.4	028	0	0 (T)	INF	--
50- 5	41.0	027	0.1-10	2 (GU)	2.0	0.5
					3.5	5.5
Note:	Sta 50-5 had two periods; the first was from radiation due to cloud passage with little or no fallout, the second period was a small but continuous increase of radiation presumably from fallout from H + 3.5 hrs to H + 9.0 hrs.					
50- 8	43.5	026	0	0 (T)	INF	--
50-10	45.5	025	0.1-10	2	2.2	8.5
Note:	Sta 50-10 had three periods recorded probably due to fractions of the cloud passing through this area, each contributing to the fallout deposited, resulting in a continuous increase of radiation until H + 10.5 hrs, one hour before station recovery.					
50-12	47.5	025	0	0 (T)	ND	--
50-15	49.2	022	0.1-10K	5 (GU)	2.5	1.0
					3.0	6.0
Note:	Sta 50-15 had two maximum periods; the first primarily due to cloud passage; the second period a small steady increase from H + 3 hrs to H + 10 hrs, time of station recovery, probably due to secondary deposition and drainage flow.					

Table 3.2 TIME OF ARRIVAL AND ESTIMATED DURATION OF FALLOUT AND/OR RADIATION FROM CLOUD PASSAGE AT GITR LOCATIONS ALONG THE PATTERN (CONTINUED)

Station No.	Station Location: Distance from GZ, Miles	Station Location: Bearing from GZ, Degrees	Characteristics of Instruments: Range mr/hr	Characteristics of Instruments: No. of Decades	Time of Radiation Arrival, H + hrs	Duration of Fallout and/or Cloud Passage Est in hours
50-17	50.5	021	0	0 (T)	ND	--
50-20	53.5	020	0	0 (T)	ND	--
60- 1	64.5	023	0	0 (T)	3.0	--
60- 3	62.5	024	0.1-10	2	2.8	2.7

Note: Station 60-3 had a small amount of fallout occur at H + 2.9 hrs. The maximum occurred at H + 4 to 5.5 hrs apparently due to material passing through this area.

70- 1	71.5	023	0	0 (T)	3.5	--
70- 3	71.0	025	0.1-10K	5 (GU)	3.5	2.0
70- 5	71.0	026	0	0 (T)	1.9	--
70- 8	70.5	028	-	- (GU)	INF	--
70-10	70.0	030	0	0 (T)	2.5	--
70-13	71.0	032	0.1-10	2 (GU)	5.7	6.0

Note: No evidence of cloud passage; steady increase in radiation at this location from H + 5.7 to H + 12 hrs, two hours before station recovery. Apparently due to diffusion of fallout from the west where the main fallout cloud and debris had been deposited.

70-14	71.0	033	0	0 (T)	ND	--
70-18	69.0	035	0.1-10	2 (GU)	9.5 doubtful	--
70-20	68.5	036	0	0 (T)	ND	--

The upper 2000 feet of the cloud (17,000 to 19,000 feet MSL) had an observed speed of 6 knots and a horizontal shear of about 50 degrees (from 20 to 70 degrees east of north). The combined effect of slower speed, and the direction and magnitude of horizontal shear would suggest a reversal in the pattern and might be reflected in the radionuclide concentrations in samples of fallout material collected from the eastern portion of the pattern. See Section 3.3.3 for discussion of radionuclide analyses.

The earliest time of arrival ranged from H + 0.4 hours at 7.2 miles from ground zero to H + 1.9 hours at 71 miles from ground zero. These times of arrival were probably due to radiation and associated with the cloud layers of higher speed from 7,000 to 10,000 feet above the ground surfaces of the valleys (11,000 to 15,000 feet MSl), travelling in a direction between 10 to 20 degrees. The duration of cloud passage and fallout deposition varied from 1.6 to 4.6 hours at these early arrival stations. See Table 3.2.

In contrast, the latest times of arrival measured were H + 7.6 and H + 9.2 hours at stations 20-1 and 20-3, respectively. Two or more phenomena were responsible for these observations that occurred after the initial distribution along the mid-line to the west of these stations. The times of arrival recorded were probably due to diffusion of suspended material remaining in the atmosphere and from whirlwinds. There were numerous whirlwinds (dust-devils) ob-

served in the crater area during the afternoon of D day. These re-suspended surface material readily. Once re-suspended, it was again subject to transport by prevailing winds from Yucca Flat into the valley where monitor stations were located northeast of Oak Springs Butte.

Also, another phenomenon became predominant in the late afternoon and evening; i.e., the diffusion and drainage flow from the higher terrain into the lower elevations. This was perhaps the most significant phenomenon in the re-distribution of less than 20 micron material that remained suspended in the area over which the original cloud travelled earlier on D-day. For example, the suspended material could have been transported out of Johnnie Water Canyon to the southeast along lateral 12 across the southern stations of lateral 20 into the Groom Lake or Papoose Lake areas; and its associated radiation was high enough to be registered on the TOAD's (2 mr/hr). Other evidence which indicates these phenomena occurred, is that particle size measurements show that in 90 percent of samples from these stations more than 50 percent of the collected radioactive material was less than 44 microns. See Section 3.3.2. The same combination of phenomena apparently extended along the eastern half of lateral 32, along most of lateral 50 and some of the eastern portion of lateral 70.

Additional interpretation of meteorological observations and conditions prevailing from H + 1 to H + 12 hours along the fallout

pattern should clarify the results obtained.

The other numbers shown in Figure 3.2 are estimates of the time of exposure due to the radioactive cloud passing over a location and the duration of the deposition of radioactive debris. These estimates were determined from the GITR radiation intensity histories by the following procedure:

(1) A plot was made of the dose rate as a function of elapsed time, and the dose rate was decay-corrected to a common time of H + 24 hours as mentioned above.

(2) The time-point at which the slope of the curve became approximately zero was located.

(3) The time interval between the time of arrival of radiation and the time-point in item 2 above thus became an estimate of the duration of the cloud passage. The time elapsed after this point represented the decay of the deposition of radioactive debris. Some of the data derived by this process is summarized in Table 3.3. Figures A.1 through A.6 in the Appendix give additional details and information concerning the passage of radioactive clouds, or the local redistribution of radioactive debris. At several locations the maximum intensity was not reached before H + 12 hours. In Figure A.6 the maximum appears to have been reached at H + 11 to 12 hours, but the removal of the instrument from the field at H + 12 hours does not permit a firm conclusion in this matter.

Table 3.3 DURATION OF CLOUD PASSAGE

Lateral	Station No.	Cloud Passage Duration*, hours
12	1	2.6
20	9	1.0
32	15	1.5
50	15	1.0
60	3	2.7

*For details see Table 3.2

3.2.2 Radiation Dosage Due to Cloud Passage and Fallout

The radiation exposure received at a given location is the result of several phenomena which may include the following: cloud passage or "sky shine", fallout *per se*, and/or suspended radioactive debris being transported from one location to another by meteorological conditions subsequent to initial deposition.

A measure of the dosages received at the various locations was determined by graphical integration of the areas under the curves on the plots of the GITR radiation intensity histories. The area to the left of the time-point at which the slope of the curve becomes zero is an estimate of the radiation due to the radioactive cloud influence; the area to the right is an approximation of the dose attributable to the deposition of radioactive debris or fallout to H + 12 hours.

Table 3.4 indicates proportions of the radiation dose (to H + 12 hours) from one location on each of five laterals. At station 1 on lateral 12 the cloud passage accounted for almost 77 percent of the total dose with the remainder due primarily to deposited fallout. On laterals 20 and 32, stations 9 and 15 respectively, the percentage was approximately 38; on lateral 50 it was down to about 19 percent. In general the dose from the cloud passage decreased and the dose from deposition increased with distance from ground zero.

Table 3.4 **PROPORTIONS OF THE RADIATION DOSE TO H + 12 HOURS FROM CLOUD PASSAGE AND FROM DEPOSITED FALLOUT**

Station No.	Dose, mr	Cloud passage*, Percent	Deposition, Percent
12 - 1	8200	76.8	23.2
20 - 9	1360	36.8	63.2
32 -15	258	38.6	61.4
50 -15	7.2	18.6	81.4
60 - 3	18.0	45.1	54.9

* For details see Appendix Table A.5

3.2.3 Field and Laboratory Decay Measurements

Field measurements are made in order to assist in the interpretation of the mechanisms of fallout and fallout characteristics. The radiation intensities recorded by the GITR's reflect the history and effects (s) of one or more combinations of events and

sources of radiation. The recorded data can include time-of-arrival of radiation, the race of deposition in a location, duration of deposition, radiation due to cloud passage, and the apparent rate of radiation decay which can reflect measurable amounts of additional radiactive material being deposited in the area during time of measurement or collection (See Section 3.2). In contrast, the characteristics of the decay of radiation determined on samples of fallout debris in the laboratory reflect only radiological decay. Therefore, the slopes of the field decay curves may be positive or negative; but the slope of the curves of the laboratory determined decay can only be negative.

Representative decay data obtained from GITR's and determined on the CH-1 in the laboratory illustrate some of the values the decay curves can have (See Figure 3.3). To minimize the effect of the cloud passage, the time interval from the estimated termination of the cloud passage to H + 10 hours (minimum time of station recovery) was used to derive the apparent field decay exponent for each of the five laterals. The low value for lateral 50 typifies the case where the rate of incoming radioactive fallout is almost equivalent to the rate of radioactive decay.

3.2.4 Indications of Secondary Deposition and Removal of Radioactivity from One Location with Time

The local meteorological conditions, diffusion and drainage flow, as described in Section 3.2.1 may well be the explanation to the phenomenon represented in Figure 3.4 where the radiation intensity

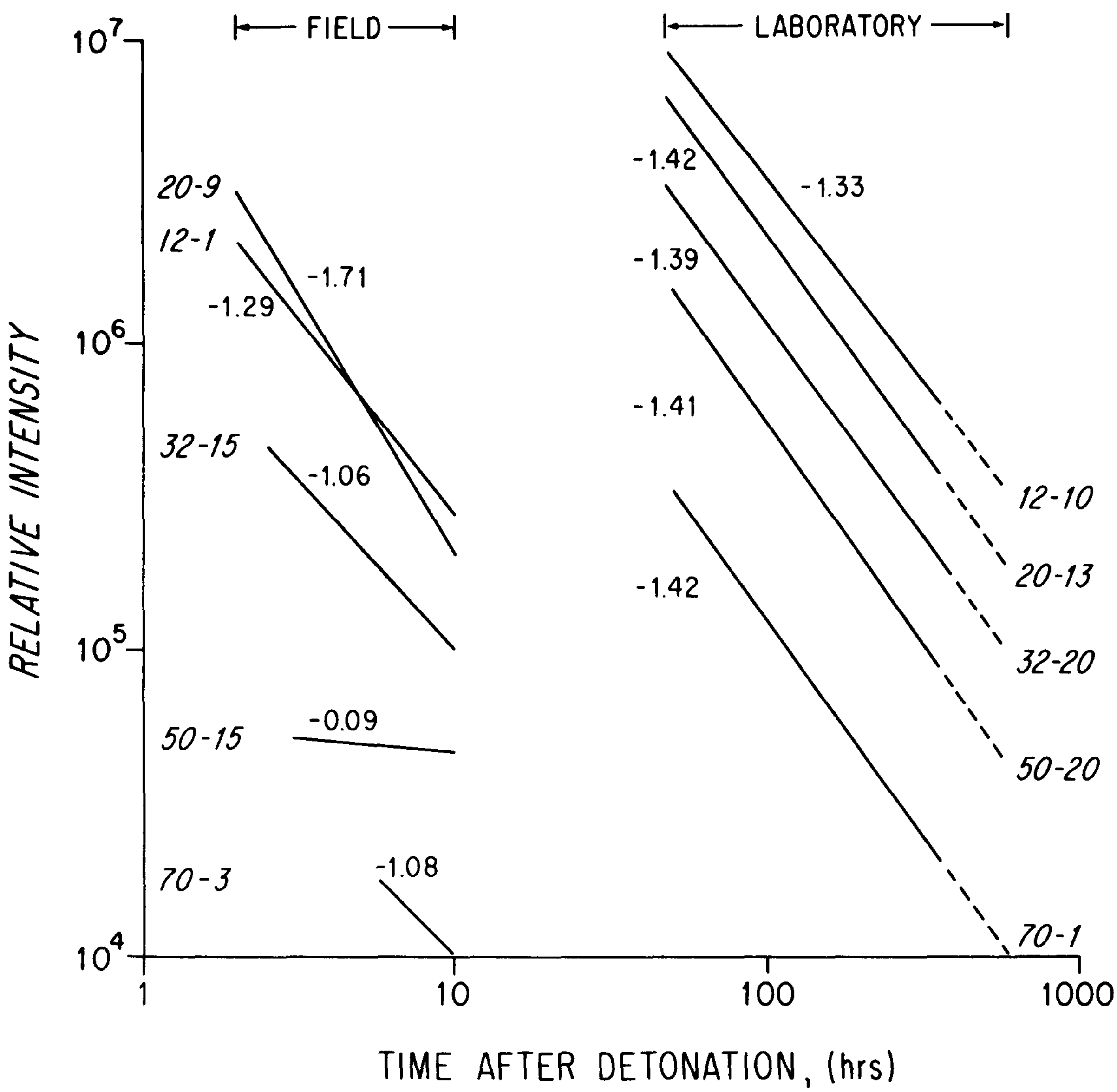

FIGURE 3.3 GAMMA DECAY CURVES AT FIELD STATIONS AND FOR SAMPLES REMOVED FROM THE FIELD TO THE LABORATORY

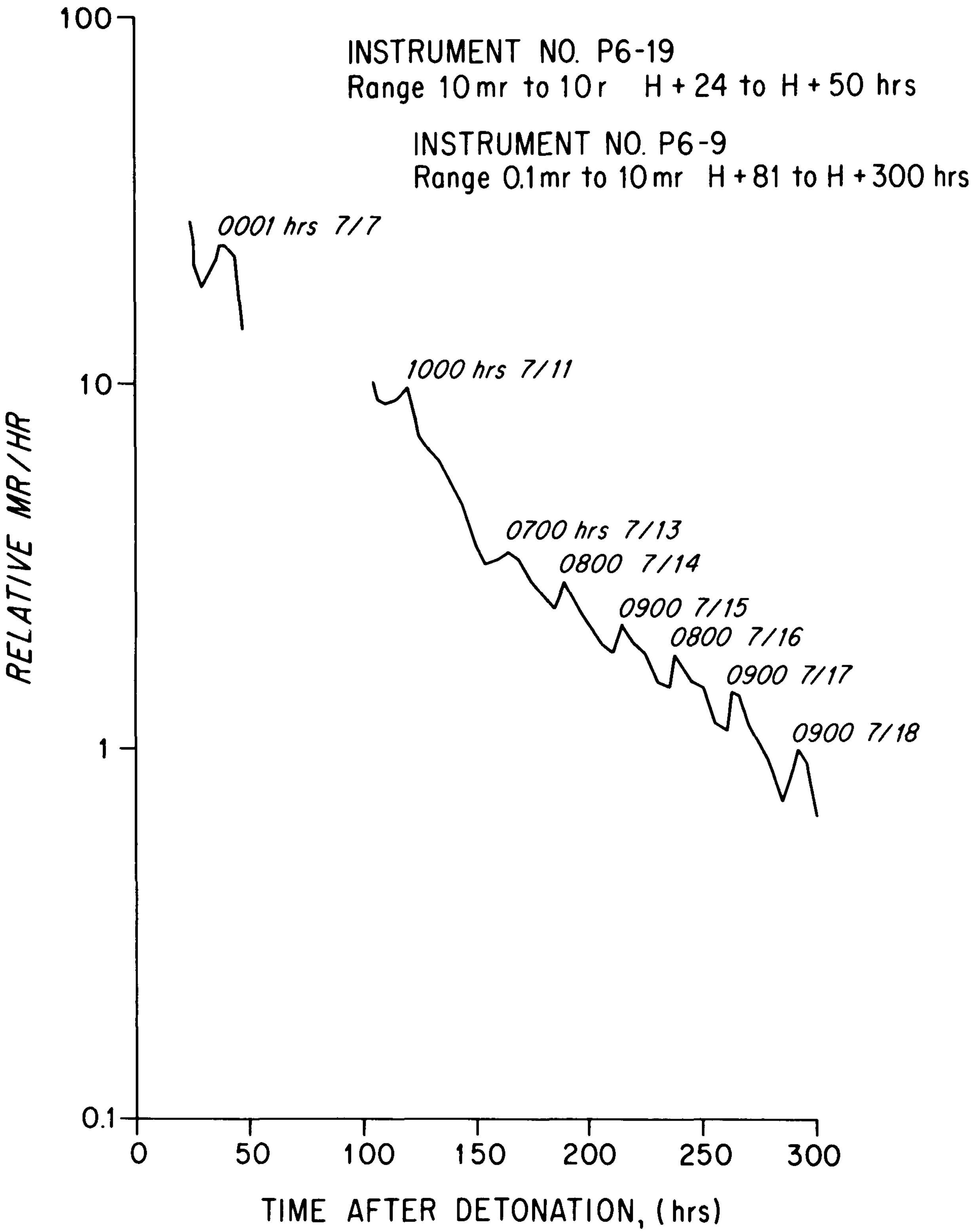

FIGURE 3.4 RADIATION INTENSITY MEASURED FROM D + 1 TO D + 13 DAYS BY GITR AT STATION 12-14

increases to a maximum each morning at approximately the same time. During the day there is a rapid decline to be followed by another sudden rise the following morning. One might speculate that there is a combined effect due to radioactive decay and movement of radioactive debris in and out of the area. Temperature variation, humidity and wind velocity may be significant in this phenomena.

3.3 FALLOUT CHARACTERISTICS

A duplicate sample of each GC was radioassayed for total gamma activity on the CH-1 System to determine the radioactivity per unit area. From these, one sample from each lateral was selected for gamma decay determinations (See Section 2.5 and Figure 2.1); 76 samples were processed routinely and separated into greater-than, and less-than 44 micron size fractions. Then, based on the total activity and the location of the collector station in the fallout pattern, samples were selected for further fractionation. Each of the resulting 13 size fractions (Section 2.4.3) was assayed for its gamma activity and weighed to determine the mass per fraction. Samples of the greater-than, and the less-than 44 micron size fractions from the most radioactive location on each of five laterals were sent to NRDL[1], and other samples for radionuclide determination were delivered to LRL[2].

---

(1) Dr. Carl F. Miller, Technical Program Director, Project Small Boy, made arrangements for these analyses.

(2) Mr. Joshua Z. Holland, Chief of the Fallout Studies Branch, Division of Biology and Medicine, made arrangements for these analyses.

3.3.1 Activity per Unit Area and per Unit Mass

Figure 3.1 shows the results obtained from the GC's located along the fallout pattern. The unit area activities ranged from a maximum value of over 10^{10} d/m/ft^2 at the most westerly station on lateral 12 to a minimum value of about 10^6 d/m/ft^2 at the most easterly stations on the laterals. In general, the unit area activity decreased with distance from ground zero.

The activity per unit mass (specific activity) also decreased from west to east along laterals 12, 20, 32 and 70. There were abrupt decreases by factors of 5 to 10 within a distance interval of one mile near some of the western stations that had maximum concentrations. The specific activity levels encountered ranged from a maximum of 65 x 10^4 d/m/mg at a station in the western part of the sector to a minimum of 1 x 10^4 d/m/mg at a station in the eastern part.

3.3.2 Particle Size Distribution

An analysis of the distribution of mass in two particle size fractions suggests a discontinuity in the values for specific activity; i. e., a lack of correlation between the activity and the mass across the fallout pattern. About 84 percent of the samples with ratios less than 1 x 10^5 d/m/mg at H + 48 hours had over 50 percent of the mass in the greater-than 44 micron size fraction. However, only 44 percent of the samples with ratios larger than 1 x 10^5 d/m/mg at H + 48 hours had over 50 percent of the mass in the greater-than 44 micron size fraction. On

an activity-mass basis 90 percent of the samples had more than 50 percent of the activity associated with the less-than 44 micron size fraction; but only 30 percent of the samples had more than 50 percent of the mass in the less-than 44 micron fraction (See Table 3.5).

Table 3.5 DISTRIBUTION OF ACTIVITY AND MASS ACCORDING TO PARTICLE SIZE

Lateral	Over 50% of Activity in*		Over 50% of Mass in	
	< 44μ	> 44μ	< 44μ	> 44μ
12	5	2	3	4
20	8	5	4	9
32	17	1	3	15
50	18	0	1	17
60	3	0	0	3
70	17	0	12	5
Totals	68 (90%)	8	23 (30%)	53

* For further details see Appendix Table A.1

A comparison of the particle size spectra of the samples fractionated into 13 size fractions shows an unusual distribution (See Figure 3.5). The stations with low specific activity values (1 x 10^5 d/m/mg) in the more easterly part of the fallout pattern had the activity present in one or two discrete size ranges; the stations with higher specific activity values (1 x 10^5 d/m/mg) in the more westerly part of the fallout pattern had the activity present in essentially all size ranges. The logical conclusion is that the fallout debris came

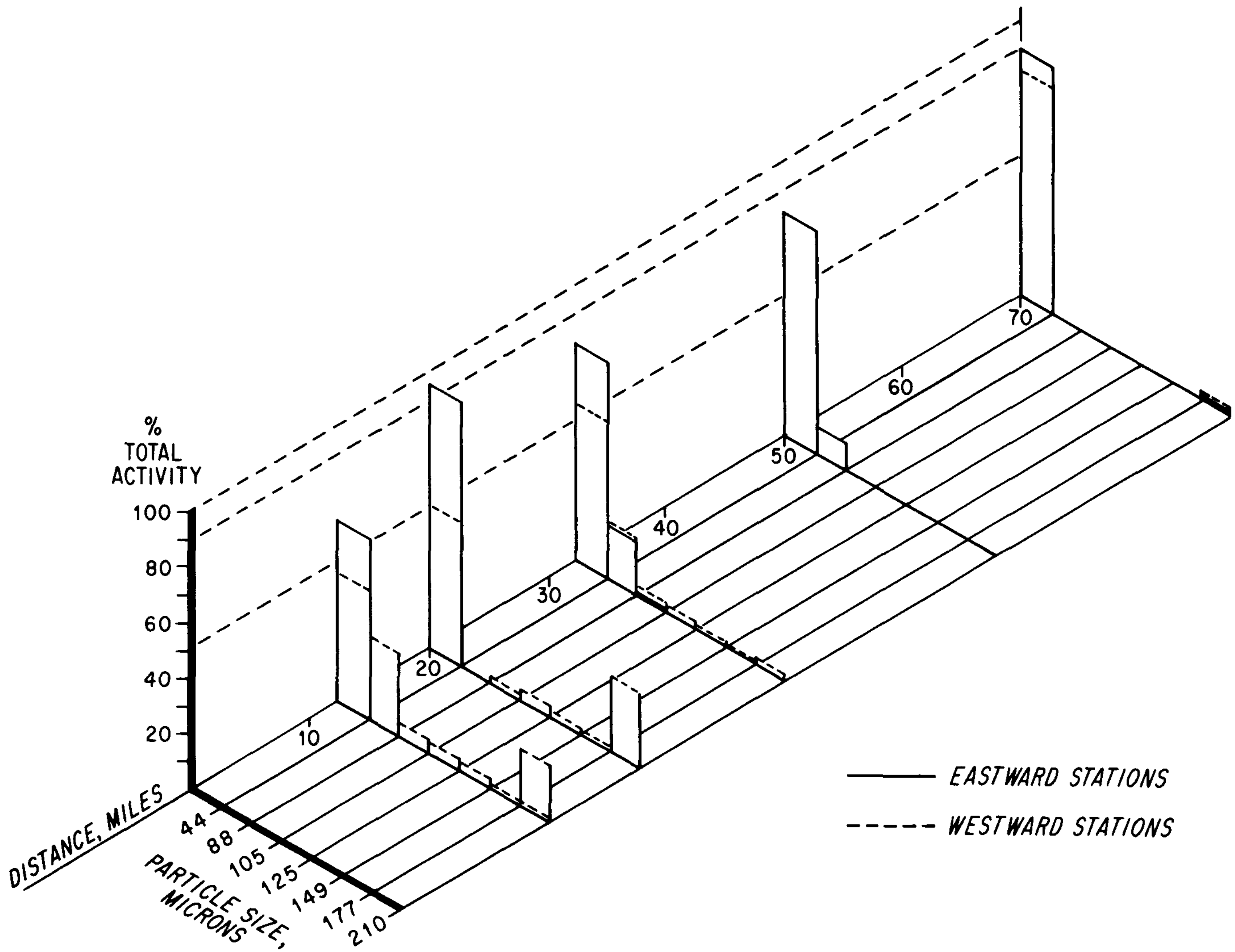

FIGURE 3.5 PARTICLE SIZE DISTRIBUTION OF RADIOACTIVITY ACROSS LATERALS AT VARIOUS DISTANCES FROM GZ

from two sources: base surge on the west side and the upper part of the cloud to the east side. Data to support this contention is presented in Table 3.6 where the percent of the total gamma activity of the <44 micron fraction is compared with the total specific activity of samples from the western and eastern stations. The total specific activity is significantly higher on western station samples; the smaller particle sizes, with some overlapping at station 5 on lateral 70, predominate on eastern station samples.

Table 3.6 RADIOACTIVITY AND SPECIFIC ACTIVITY ACROSS THE FALLOUT PATTERN

Station No.	Location on Lateral	Gamma Radioactivity, % of Sum Total in <44	Specific Activity* 10^5 d/m/mg (total)
12-13A	Western	46.4	4.39
32-17B	Western	52.2	5.14
70- 5B	Western	82.7	7.50
12- 6A	Eastern	66.5	0.25
32-13A	Eastern	79.2	0.62
70-18A	Eastern	90.0	0.51

*For details see Appendix Table A.2

3.3.3 Some Indications of Fractionation of Radionuclides*

In addition to these findings the results of the radiochemical analyses indicated a distance relationship and provided evidence of

* No results are presently available from the samples sent to LRL in December 1962.

fractionation. The data from NRDL are incomplete with 25 instances where values were not reported for both fractions of the same sample; but some conclusions can be suggested. There was a general decrease in the enrichment of Sr^{89} (relative to Zr^{95}) in the less-than 44 micron fraction from a factor of 5.6 at Station 12-10A to a factor of 1.7 at Station 70-1A. Also, the less-than 44 micron range appeared to be enriched in Sr^{89} significantly more than the greater-than 44 micron size range. On Lateral 50, as one might predict, there was a contrast to the other laterals. The Sr^{89} was depleted by a factor of 3.7 in both size ranges (See Table 3.7). This supports the contention that the fallout material on the westward stations was different from that on the eastward stations.

A comparison of the data of some of the other nuclides indicated similar differences. For example, the more refractory nuclides from the westward stations were not fractionated from Zr^{95} in the greater-than 44 and less-than 44 micron size ranges; but fractionation of those nuclides did occur in the less-than 2 micron size fraction of the same sample. The more volatile nuclides were fractionated to a lesser degree in the smallest size range. On the eastward stations, however, (particularly on Lateral 50) a depletion by a factor of 4 to 28 was indicated for the more volatile Sr^{89}, Sr^{90}, Sr^{91}, I^{131}, I^{136} and Cs^{137}.

Table 3.7 NUCLIDE FRACTIONATION AS RELATED TO PARTICLE SIZE AND DISTANCE

Values are fractionation factors*, ratios of equivalent fissions of a given nuclide to equivalent fissions of Zr95, dimensionless. NR, not reported. LT, less than; GT, greater than 44 microns.

Station No. Size Fraction	Zr95	Sr89	Sr90	Sr91	Mo99	I131	I132	Cs136	Cs137	Ba140	Ce141	Ce144
12-10A												
LT 2		NR	NR	NR	4.04	NR	0.56	1.85	1.96	NR	19.6	6.78
LT 44		5.62	5.34	NR	NR	3.85	2.53	6.15	5.91	3.16	2.10	1.40
GT 44		NR	NR	1.62	1.15	1.19	NR	1.12	0.86	1.06	1.19	1.21
20-13A												
LT 44		4.11	3.99	3.74	1.25	2.26	NR	1.64	6.24	NR	1.35	1.26
GT 44		NR	NR	1.41	1.10	0.82	0.58	NR	NR	8.61	1.08	1.10
32-20A												
LT 44		3.72	3.60	3.24	NR	2.53	NR	1.83	3.41	2.30	1.46	1.28
GT 44		NR	NR	1.27	1.07	NR	0.68	NR	NR	0.80	0.79	0.95
50-20A												
LT 44		0.27	0.27	NR	0.115	0.04	NR	0.14	0.24	0.19	NR	NR
GT 44		0.27	0.63	NR	1.44	0.22	NR	NR	NR	0.79	NR	NR
70- 1A												
LT 44		1.71	1.65	NR	0.98	NR	NR	1.04	1.96	1.27	NR	NR
GT 44		0.23	0.41	NR	7.61	NR	0.57	NR	NR	0.72	0.01	1.08

* Data from NRDL Analysis by Tracerlab

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

1. Adequate samples of fallout were obtained to delineate the eastern part of the fallout pattern from 7 to about 70 miles from ground zero.

2. No correlation between radioactivity and mass was found.

3. Considerable differences occurred in fallout time of arrival and its duration across the fallout pattern beyond 20 miles from ground zero. In general the dose from cloud passage decreased and the dose from deposition increased with distance.

4. Enough shear of the cloud occurred to permit a comparison of the isotopic fractionation which existed above 10,000 feet MSL; but the data is limited to incomplete results from only five samples. The radiochemical analyses indicated a distance relationship and provided evidence of fractionation that substantiated a difference between the fallout debris from two levels of the cloud.

5. The data indicated that topography had a significant influence on the activity per unit mass, the particle size distribution, and the fractionation of the fission product nuclides.

4.2 RECOMMENDATIONS

1. A single administrative group or laboratory responsible for both collection and chemical analyses of samples would expedite the dissemination of data through reports.

2. In future studies of this type, it would be desirable to

have a minimum capability of establishing stations along laterals of a length equal to one half of the distance from ground zero.

3. In concurrence with Part II of this report it is clear that more research is needed if a workable conversion factor is to be established between count rate at 500 feet in the air and dose rate at 3 feet above the soil surface. A minimum effective area is a basic requirement to insure that no attempts are made to pinpoint an aerial reading to one specific point on the ground.

PART II - AERIAL RADIOMETRIC SURVEY

CHAPTER 5

INTRODUCTION

5.1 OBJECTIVES

The primary objective of CETO Project 62.80, Aerial Radiometric Surveys, was to determine the areal distribution of Sedan fallout deposited on the ground. Information obtained by aerial surveys in the area from 10 to 200 miles from ground zero was to be used by other CETO projects in determining the places where plant, animal, and soil specimens were to be collected.

Secondary objectives, if time and the nature of the fallout pattern permitted, included obtaining data to improve the correlation between ARMS-I and -II, and to study: the decay in gamma count rate at 500 feet (aerial gamma decay), in contrast to the decay in dose rate from debris on the ground as a function of time and distance from ground zero; the conversion of count rate at 500 feet to dose rate at 3 feet as a function of time and distance from ground zero; the attenuation with altitude of gamma-rays from fallout as a function of time and distance from ground zero; and the feasibility of collecting aerial gamma energy spectra.

5.2 BACKGROUND

Experimental aerial measurements of terrestrial radioactivity were conducted in the United States as early as 1948 to establish the feasibility of aerial prospecting for uranium ore. Studies of the USGS and Oak Ridge National Laboratory (ORNL) led to the development of instrumentation and techniques (Reference 26) which were used in June 1950 to make the first systematic aerial survey of a large

area (1600 square miles) in the United States. The Environmental Radiation Division (EnRad) of the University of California at Los Angeles (UCLA) and CETO proof-tested the equipment and techniques of the USGS-ORNL System during the Fall Environmental Survey, 1956 and included the mapping of the residual hot-line of radioactive debris from Shot Met,Operation Teapot (1955). This system and technique was used by UCLA routinely to determine fallout patterns during Operation Plumbbob (1957) and 4 patterns during Hardtack II (1958). A revised aerial survey system, ARMS II, (References 27 and 28) was developed in 1960 for CETO by EG&G. ARMS-I and -II were used in conjunction with LRL/UCLA studies of the fallout pattern from Shot Danny Boy, March 1962.

5.3 THEORY

The gamma-ray activity at 500 feet above the ground measured by ARMS scintillation-detection equipment has two principal sources: terrestrial and non-terrestrial. The non-terrestrial sources include: cosmic radiation, radionuclides in the atmosphere, and extraneous sources such as aircraft contamination and Cs^{137} calibration sources. Terrestrial sources are the radionuclides in the surficial materials of the earth. It is not possible to measure directly the relative contribution of each source at a particular time while surveying, but certain assumptions and calibration procedures permit reliable estimates to be made of the components of the gross gamma radiation.

The count rate at 2000 to 3000 feet above the ground, where negligible radiation from the ground is present, is considered to be the non-terrestrial radiation. The cosmic radiation component at

500 feet above the ground is due mainly to the air-scattered gamma-rays induced by cosmic particles. The natural radio-nuclides in the atmosphere are assumed to be uniformly distributed and their contribution to the non-terrestrial component is normally small. Surveys of a fallout pattern from a nuclear detonation are not made until D + 1 day or later, so most of the fallout has deposited on the ground or moved out of the area. If any fission products remain in the air, they are assumed to be uniformly distributed. The non-terrestrial count rate is measured each day before, during, and after ARMS flights and is subtracted from the gross count at 500 feet above the ground to give the net terrestrial gamma count rate that is recorded.

The terrestrial component of the gamma radiation found at 500 feet above the ground comes from the radionuclides in the surficial few inches of earth materials. The effective area of response on the ground for an ARMS detector at 500 feet above the ground is about 1500 feet in diameter and the recorded count rate is an average of the radiation received from this area. Potassium-40 and members of the uranium and thorium series in soil and, to a lesser extent, in rock are the major natural sources of gamma-rays. The contribution of the natural gamma background to the net count rate within a fallout pattern ranges from as much as 50 percent on the edges of the fallout pattern to less than 0.1 percent at the midline or maximum intensity. Measurement of the pre-shot background makes it possible to determine the count rate due to debris deposited after a particular event in the case of previous contamination.

Adequate data of the type referred to as secondary objectives in Section 5.1 for the conversion of count rate at 500 feet over the entire area of a fallout pattern to dose rate at 3 feet do not exist. This problem is complicated by the variable response of field dose rate meters and the necessity for detailed dose rate and count rate measurements in all parts of the fallout pattern. In an initial study of this problem it was determined during Operation Plumbbob (1957) that a count rate of approximately 77,000 counts/sec. measured 500 feet above the ground by ARMS I was equivalent to 1 mr/hr measured 3 feet above the ground with a Radiac Model AN/PDR-TIB (Reference 8, 16). In this study it was found that the response of various dose rate survey meters varied by at least a factor of 2.

The ARMS-II instrumentation was designed to give count rate data comparable to the data of the existing ARMS-I equipment. Both units were flown over the Extended Source Calibration Area (ESCA) at the NTS in 1960 and the results of the test have been published (Reference 29). The ESCA range was a square 2000 feet on a side and contained 400 sources. Over Co^{60} sources producing a ground dose rate of about 0.2 mr/hr the count-rate to dose-rate conversion factor was about 25,000 counts/sec at 500 feet equal 1 mr/hr at 3 feet. This conversion factor is low because the ESCA range was not large enough to be a broad source to a detector at 500 feet above the ground.

Additional data are needed before the conversion of count rate to dose rate will be understood.

CHAPTER 6

PROCEDURE

6.1 OPERATIONS

The participation of CETO Project 62.80 in the Shot Sedan event was in two phases: pre-shot and post-shot.

6.1.1 Pre-Shot Sedan. The pre-shot participation consisted of an aerial survey of the four arcs in the northeastern quadrant to determine the gamma background activity. In addition the fallout pattern of Shot Des Moines was surveyed from Nevada Highway 25 to U.S. 50 near Ely, Nevada, and Gold Flat and Kawich Valley were surveyed to determine the residual radiation from the fallout of Shots Danny Boy and Des Moines in those areas. (See Table 6.1).

Ground gamma energy spectral measurements were made near Highway 25 in the area contaminated by Shot Des Moines on the evening of July 5. Aerial measurements of gamma energy spectra at 100 feet were made over the same locations early on the morning of July 6.

6.1.2 Post-Shot Sedan. Post-shot operations started on D + 1 day (July 7). ARMS-I and ARMS-II flew missions as indicated in the above table. Radioactive dust in the air south of Highway 25 on July 8 delayed the survey in that area until the following day.

Gamma energy spectral measurements were made on the evening of July 9 at the ground surface near Highway 25 in the area contaminated by Shot Sedan. Aerial gamma energy spectral measurements over the Sedan fallout pattern near Highway 25 were made by ARMS-II on July 10.

Table 6.1 AERIAL AND GROUND RADIOLOGICAL SURVEYS FOR SHOT SEDAN

Dates	Areas surveyed by Ground	ARMS-I	ARMS-II
		Pre-Shot Sedan	
6/26		70 mile (Arc 2) 90 mile (Arc 3) 160 mile (Arc 4)	
6/27		Arc 2 Arc 3 Arc 4 40 mile (Arc 1) to Arc 4 (U.S. 50) (Shot Des Moines)	
6/30		Arc 1 (Near U.S. 50 (Des Moines)	Arc 1 Gold Flat Kawich Valley
7/5	Near Hwy 25 (Shot Des Moines)		
		Post-Shot Sedan	
7/7		Arc 1 to NE of Ely	N boundary NTS to 60 miles
7/8		Beyond 70 miles	Did not fly
7/9	Near Hwy 25 (Sedan)		S of Hwy 25
7/10		Re-surveys Salt Lake City (Small Boy Bkg)	Near Hwy 25 (Sedan)

Aerial gamma energy spectra were taken over several ground positions where the ground dose rate had been measured several hours earlier with a survey meter (Victoreen Instrument Co., Model 440). Data were recorded at 100 feet above the ground surface on one mile transects parallel to or along the hot line of fallout. Sufficient flight transects were made to build the large air-scatter peak to maximum channel capacity (10^6 counts).

Gamma energy spectral measurements were made on specimens of collected vegetation (sagebrush) from these same locations at various times for about one month.

6.2 INSTRUMENTATION

The ARMS-I and ARMS-II systems use thallium-activated sodium iodide crystals and photomultiplier tubes to detect gamma radiation. Different electronic techniques are used to handle the pulses from the photomultipliers but the count rates of the two systems are comparable.

6.2.1 ARMS-I. The ARMS-I system of the USGS is installed in a DC-3 aircraft, a part of an integrated aerial geophysical system.

The gamma radiation-detection equipment was designed by the Health Physics Division of ORNL and has been described elsewhere (Reference 26). This system has three detecting elements to cover an equivalent range in gamma radiation count rate up to 3×10^6 counts/second. The high sensitivity element consists of six thallium-activated sodium iodide crystals each 4 inches in diameter and 2 inches thick, and six photomultiplier tubes connected in

parallel. The other two detecting elements utilize a 1.5 inch and 1.0 inch sodium iodide crystal with associated photomultiplier tubes.

6.2.2 ARMS-II. The ARMS-II system of EG& G is installed in a Beech Model 50 Twin Bonanza. The apparatus consists of three sub-systems: the radiation detection and measurement sub-system, the aircraft space-positioning sub-system, and the information printout sub-system. The functions of these sub-systems and their components have been described elsewhere (Reference 28).

A 400 channel pulse height analyzer (Technical Measurements Corporation (TMC), Model 401), a control and power unit (TMC Model 520 P), and an integral Harshaw assembly probe (1 7/8 inch x 2 inch NaI (Tl) and photomultiplier tube) were mounted in the ARMS-II aircraft to record gamma energy spectral data.

6.2.3 Calibration. The ARMS-I and ARMS-II gamma radiation detectors are calibrated with Cs^{137} according to the method described in Reference 29. The two techniques differ in minor details but they are generally similar. Briefly, the procedure consists of positioning a small cesium-137 source adjacent to the crystals, setting the energy discriminator at 662 kev, and adjusting the gain to obtain a predetermined count rate. This calibration procedure on both aircraft requires less than 1 minute and is performed periodically during survey operations.

The pulse height analyzer was calibrated with the Cs^{137} source in the ARMS-II aircraft.

6.3 DATA REQUIREMENTS

The raw count rate data recorded in the air by ARMS-I on graphic milliammeters and by ARMS-II on decimal tape were plotted on maps and transmitted to the author. The count rate data were then corrected for decay, converted to dose rate, and contoured.

6.3.1 ARMS-I Data Recording and Reporting. The ARMS-I aeroradioactivity data were recorded as continuous profiles on strip chart recorders. In view of the requirement for early use of the data, however, the ARMS-I count rate was also periodically entered on the observer's copy of the flight map (1/250,000 scale) as the survey progressed. After the flight was completed, the continuous profiles were used in editing and adding detail to the map prepared while in flight. This map, which showed the radiation intensities along the flight path of the aircraft, was available shortly after each flight.

6.3.2 ARMS-II Data Recording and Reporting. ARMS-II aeroradioactivity data and the locations of data points were recorded on decimal tape. The major features of the fallout pattern were noted on the flight map to provide inflight characterization of the pattern for additional detail surveying and to have information on the location of the fallout radiation levels available as soon as the flight was completed, similar to the ARMS-I operation. Upon completion of each mission the decimal tape was edited and significant data points plotted on tracing paper at a scale of 1/250,000. The data were then graphically

corrected for minor "Doppler error" and compiled on a 1/250,000 scale map. This map, which showed count rate, had data points plotted with an accuracy of .05 inches and normally was completed less than 8 hours after each flight.

6.3.3 Data Reduction. The first step in reducing the ARMS data was to correct the count rate for radioactive decay. Sufficient data were available to allow estimating to within 15 minutes the time a particular area was surveyed. The data were corrected for decay to H + 24 hrs. using the classical factor, $T^{-1.2}$.

After correction for decay, the data were converted from count rate at 500 feet above the ground to dose rate at 3 feet. The conversion factor used for this operation was: 50,000 counts/sec at 500 feet = 1 mr/hr at 3 feet.

The H + 24 hrs. dose rate data, at a scale of 1/250,000 were contoured using 100, 50, 20, 10, 5, 2, 1, 0.5, and 0.1 mr/hr contour lines. The contour map of the fallout pattern was then reduced in scale from 1/250,000 (4 miles = 1 inch) to 1/1,000,000 (16 miles = 1 inch).

Interpretation of the gamma energy spectral data consisted of identifying isotopes primarily by half-life measurements on the sagebrush sample photopeak activities, secondarily on energies and where possible, on abundance ratios. The sagebrush spectra and aerial spectra were then compared to see what isotopes could be detected from the air.

CHAPTER 7

RESULTS AND DISCUSSION

7.1 RESULTS

The pre-Sedan background aeroradioactivity ranged from about 500 to 1500 counts/sec, except in the area of fallout deposition from Shot Des Moines. This fallout pattern was surveyed by ARMS-I on June 27, 28, and 30, 1962, from Highway 25 to U. S. Highway 50 and is shown in Figure 7.1. The contours show gamma count rate above the assumed pre-Des Moines background of 1000 counts/sec. Approximate Des Moines H + 24 dose rates in mr/hr can be obtained by dividing the contour values by two. Airborne contaminants obscured the Des Moines fallout pattern from Highway 25 to the test site boundary on June 30. Venting of the Marshmallow tunnel on the evening of June 29 is believed to have been the source of this airborne activity. Figure 7.2 shows profiles recorded along Highway 25 by ARMS-I and II on the morning of June 30. The moderate count rates recorded by ARMS-II before 0630 hrs(8000-16000 counts/sec) were not observed by ARMS-I at 0730 hrs(3000-4000 counts/sec) and by 1100 hrs airborne activity was almost background.

The aerial surveys of CETO Project 62.80 mapped the fallout pattern of Sedan to a distance of 200 miles from ground zero (Figure 7.3).

The fallout pattern is clearly asymmetric; the contours on the west portion of the pattern show a steep gradient, the hot line or line of maximum radiation intensity is west of the geo-

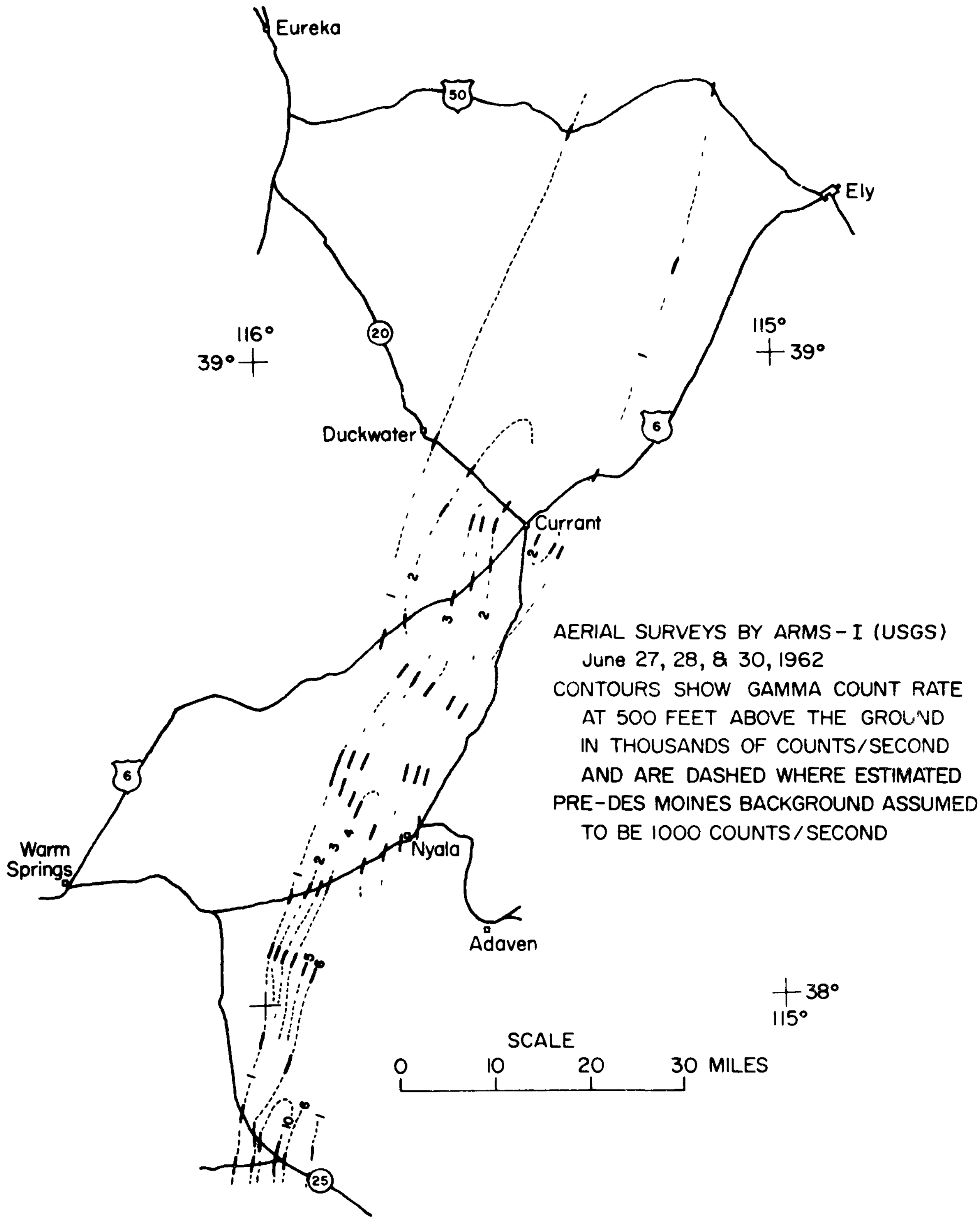

FIGURE 7.1 AERORADIOACTIVITY MAP OF FALLOUT FROM DES MOINES EVENT

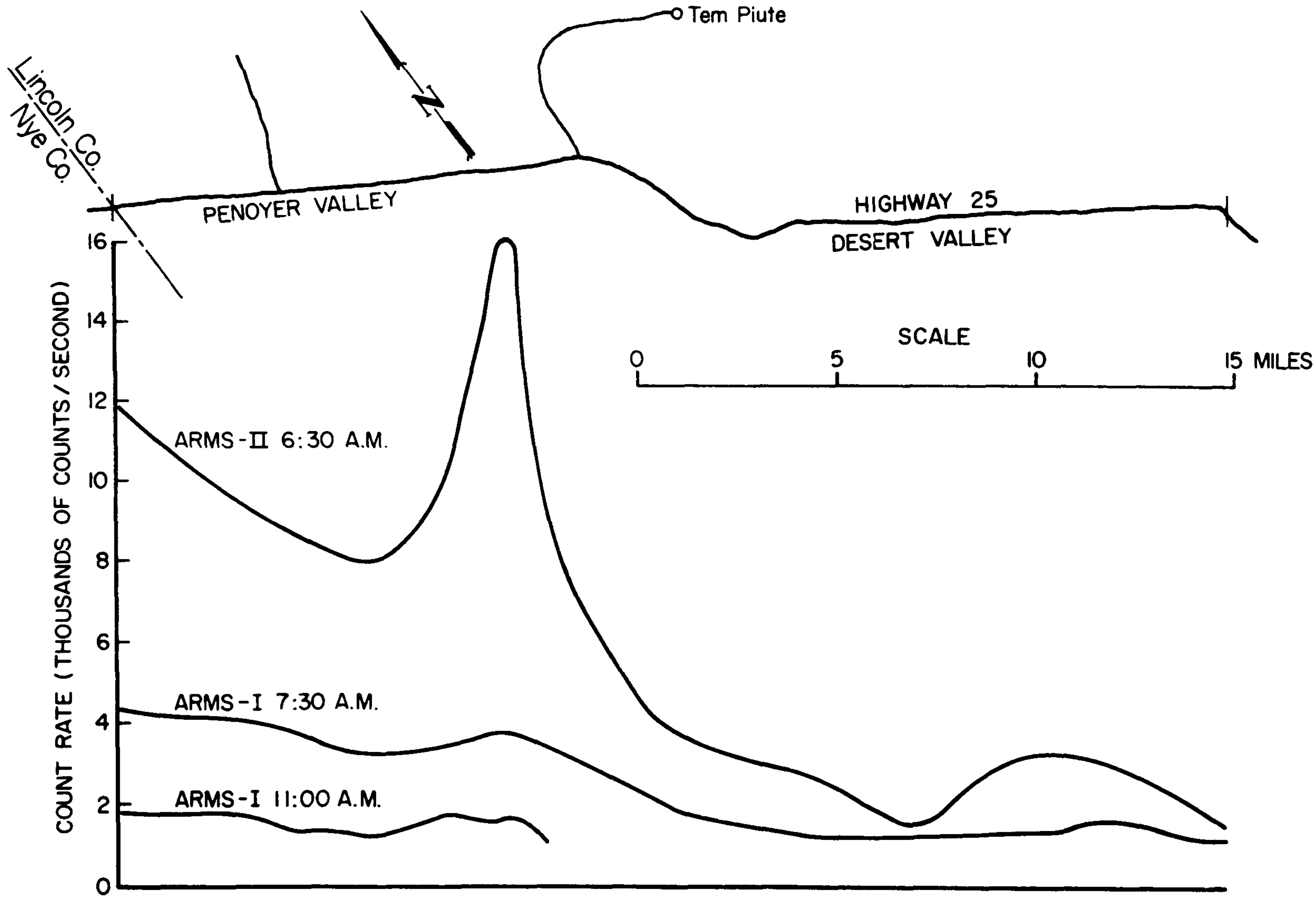

FIGURE 7.2 AERORADIOACTIVITY PROFILES ALONG HIGHWAY 25, JUNE 30, 1962
GAMMA COUNT RATE AT 500 FEET ABOVE THE GROUND IN THOUSANDS
OF COUNTS/SECOND

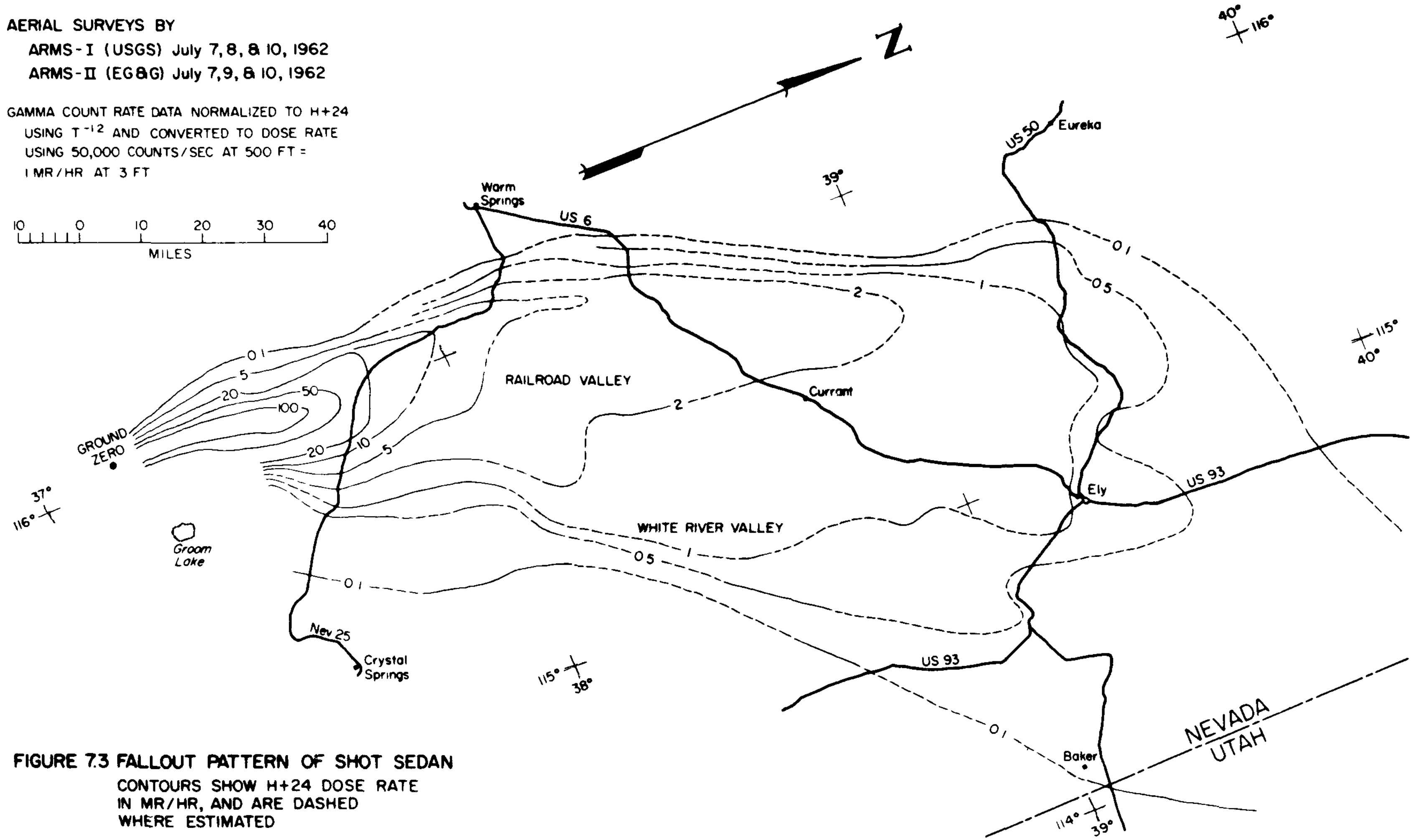

FIGURE 7.3 FALLOUT PATTERN OF SHOT SEDAN
CONTOURS SHOW H+24 DOSE RATE IN MR/HR, AND ARE DASHED WHERE ESTIMATED

graphic center line of the pattern. The contours on the east indicate a "feathering out" or gradual reduction in amount of fallout. This pattern is consistent with the shearing to the east of the upper portion of the cloud.

The area contaminated by Shot Des Moines was completely covered by Shot Sedan debris and the count rate due to Shot Des Moines was less than 5 percent of the count rate recorded post-Shot Sedan. Fallout from Shot Sedan was probably present where net count rates of more than 2500 counts/sec (and even 2000 counts/sec) were observed.

The western edge of the area of detectable fallout, was less than 5 miles from the 0.1 mr/hr contour lines. The northern and eastern edges of the fallout pattern, however, were not as well defined. Fallout was detected at least 30 miles north of the 0.1 mr/hr contour lines.

Photopeak energies present in the spectra from the fallout on sagebrush were: .06, .08, 0.14, 0.22, 0.36, 0.40, 0.48, 0.67, 0.78, 0.94, 1.14, 1.44, and 1.60 Mev. Comparison of this tabulation to that of the aerial spectra shows that the six peaks below 0.48 Mev on the sagebrush are obscured by a large air-scatter peak. The weak peaks at 0.78 and 1.44 Mev from the sample were not resolved on the aerial spectra. The energy peaks common to both spectra are: 0.48, 0.67, 0.94, 1.14, and 1.60 Mev. Preliminary analysis of the data indicates the presence of I^{131}, Te^{132}, I^{132}, W^{187}, and Ba^{140}-La^{140}.

7.2 DISCUSSION

Data obtained on resurveys of areas within 50 miles of ground zero were found to be inconsistent in several places. The inconsistencies are attributed to an increase or decrease in the amount of debris on the ground at a particular location because of redistribution of debris by the wind or to radionuclides in the air. Airborne debris could have resulted from wind pickup or from the dust clouds that were seen to rise from Sedan crater for several days after D day. At about H + 27 hours at 6000 feet above the ground, south of Mercury, ARMS-II recorded more than 50,000 counts/sec while flying through a haze layer that appeared to come from the Sedan crater. Visible dust was also observed north of ground zero. on D + 1 day.

Excellent ARMS-I data along Highway 25 on D + 1, 2, and 4 days permit determination of an "aerial gamma decay" at this location. The count rates of twelve features on profiles obtained at H + 22, + 50, and + 94 hours were plotted and the value of the decay exponent determined. Between H + 22 and H + 50 hours it ranged from -0.6 to -0.9 with an average of -0.8. Between H + 50 and H + 94 hours it ranged from -1.9 to -2.3 with an average of -2.1. Considering only H + 22 and H + 94 hours the range was -1.25 to -1.50 and the average was -1.40. Unfortunately, sufficient data in other parts of the fallout pattern were not obtained to determine whether this two-part "aerial gamma decay" curve is typical or atypical. Decay exponents based on D + 1 and D + 4 days data were determined for Railroad Valley west

of Nyala Ranch (-1.2), Currant (-1.5), and U. S. 50 west of Ely (-1.0). In the absence of definitive "aerial gamma decay" data for different parts of the fallout pattern, the classic $T^{-1.2}$ decay has been used in normalizing count rates to H + 24 hours.

An arbitrary count rate to dose rate conversion factor, 50,000 counts/sec at 500 feet = 1 mr/hr at 3 feet, was used in this study because of conflicting ground and aerial data which probably resulted from redistribution and airborne debris. Previous studies of the conversion factor problem have yielded conflicting data, due in part to the sources on the ground having different energies and to different instruments being used to determine the ground dose rate.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The primary objective of CETO Project 62.80 was accomplished. The areal distribution of Shot Sedan debris deposited on the ground was determined by aerial surveys from 10 to more than 200 miles from ground zero. The general features of the fallout pattern were known by the evening of D + 1 day and this information was made available to other CETO projects.

The secondary objectives were only partially realized. An improved correlation between ARMS-I and II was obtained. Some information on "aerial gamma decay", conversion of aerial count rate to ground dose rate, amd attenuation of gamma-rays with altitude was obtained but more data are needed. The feasibility of obtaining aerial gamma energy spectral data was demonstrated.

In view of the uncertainty in the "aerial gamma decay" and the conversion of aerial count rate to ground dose rate, the dose rates given in Figure 7.3 must be used judiciously. This is especially true in the fringe areas of the fallout pattern where background radiation may account for 20 to 50 percent of the count rate recorded on D + 3 or 4 days.

8.2 RECOMMENDATIONS

The efficiency of aerial radiometric measurements in delineating fallout patterns has been demonstrated. The technique is proven and the count rate data are reliable and internally consistent when suspended fallout debris is avoided. The present need is for sufficient coordinated ground and aerial data to permit converting the aerial count rate data to ground dose rate data.

The following example illustrates how the necessary data could be obtained in an ideal situation. Pre-shot background gamma data would be determined before the detonation. Afterward, one aircraft would delineate the fallout pattern on D + 1 day to about 200 miles from ground zero. A second aircraft would devote full time to obtaining data related to detailed understanding of various conversion factors. The second aircraft would survey pre-determined laterals at about 10,30,60, 120 and 180 miles from ground zero,the location chosen on the basis of information received from the first aircraft.

The data recorded on each lateral would include: spectral data at 100, 200, 300, and 500 feet above the ground surface and net gamma count at 100, 300, 500, 700, and 1000 feet with 500 foot increments

thereafter until terrestrial activity could not be detected. Concurrent ground surface measurements would be made with sensitive dose rate meters.

APPENDIX A

DATA ON DECAY, PARTICLE SIZE, UNIT AREA ACTIVITY, RESIDUAL ACTIVITY ON PELLETS AND RADIATION DOSAGE

Table A. 1 PARTICLE SIZE DISTRIBUTION ACCORDING TO ACTIVITY AND MASS

Percent of activity determined at time of counting

Station Number	Percent of Activity in <44µ	Percent of Activity in >44µ	Percent of Mass in <44µ	Percent of Mass in >44µ
12- 1	52.6	35.3	55.8	44.2
12- 3	13.3	77.5	42.6	57.4
12- 4	70.0	17.4	20.0	80.0
12- 6	64.2	28.3	23.2	76.8
12-11	80.2	10.7	21.0	79.0
12-13	47.6	44.4	50.5	49.5
12-14	41.7	47.3	50.8	49.2
20- 1	65.7	28.2	22.5	77.5
20- 2	91.3	5.4	27.8	72.2
20- 3	55.9	33.9	11.0	89.0
20- 4	61.5	32.2	5.8	94.2
20- 5	56.0	37.9	34.8	65.2
20- 6	38.6	55.6	53.3	46.7
20- 7	55.7	38.2	63.2	36.8
20- 8	48.2	45.9	37.7	62.3
20- 9	30.2	63.5	48.9	51.1
20-10	44.6	49.4	58.4	41.6
20-11	71.2	24.5	54.1	45.9
20-12	88.5	7.6	28.1	71.9
20-13	40.6	53.5	37.0	63.0
32- 2	70.5	20.7	48.5	51.5
32- 3	62.2	29.0	41.0	59.0
32- 4	74.0	17.1	56.3	43.7
32- 5	74.7	16.3	44.1	55.9
32- 6	77.6	14.3	59.6	40.4
32- 7	67.5	24.2	38.6	61.4
32- 8	67.2	23.8	42.5	57.5
32- 9	66.1	25.1	32.2	67.8
32-10	68.0	27.7	39.0	61.0
32-11	58.7	32.3	6.0	94.0
32-12	78.1	13.8	20.2	79.8
32-13	78.0	22.0	52.0	48.0
32-14	57.3	36.4	5.3	94.7
32-15	47.1	43.8	32.0	68.0
32-16	60.0	29.8	36.9	63.1
32-17	57.2	32.8	28.7	71.3
32-18	73.4	16.5	49.3	50.7
32-19	39.4	51.8	40.2	59.8

Table A.1 PARTICLE SIZE DISTRIBUTION ACCORDING TO ACTIVITY AND MASS

(CONTINUED)

Station Number	Percent of Activity in <44µ	Percent of Activity in >44µ	Percent of Mass in <44µ	Percent of Mass in >44µ
50- 1	51.2	39.9	12.9	87.1
50- 2	70.4	20.5	36.2	63.8
50- 3	61.8	29.2	17.1	82.9
50- 4	58.9	34.4	32.6	67.4
50- 5	71.3	19.7	5.6	94.4
50- 6	60.1	28.2	15.0	85.0
50- 7	62.5	26.9	10.0	90.0
50- 9	65.2	25.9	23.3	76.7
50-10	78.5	12.5	31.7	68.3
50-11	67.4	23.6	20.9	79.1
50-12	74.2	18.6	14.9	85.1
50-13	74.2	16.8	35.1	64.9
50-14	71.8	19.2	64.6	35.4
50-15	79.0	17.1	13.8	86.2
50-17	74.6	19.0	19.1	80.9
50-18	79.2	16.2	19.2	80.8
50-19	61.0	30.0	17.6	82.4
50-20	61.5	29.6	21.5	79.5
60- 1	70.0	20.2	34.2	65.8
60- 2	66.9	22.9	33.7	66.3
60- 3	80.4	10.0	35.7	64.3
70- 1	80.5	15.4	60.8	39.2
70- 2	87.4	8.6	78.8	21.2
70- 3	79.7	13.7	59.4	40.6
70- 4	81.4	14.3	65.0	35.0
70- 5	80.1	14.4	59.0	41.0
70- 6	84.1	11.9	60.5	39.5
70- 7	86.6	10.7	59.7	40.3
70- 8	86.0	10.2	10.0	90.0
70- 9	84.9	13.8	34.3	65.7
70-10	85.9	11.5	41.0	59.0
70-12	89.0	7.6	56.5	43.5
70-14	73.0	19.4	78.2	21.8
70-16	82.0	13.9	54.8	45.2
70-17	72.9	23.4	28.7	71.3
70-18	86.4	10.3	57.1	42.9
70-19	80.8	15.1	35.6	64.4
70-20	80.0	15.9	50.6	49.4

Table A. 2 GAMMA ACTIVITY AND MASS DISTRIBUTION ACCORDING TO PARTICLE SIZE

CH-1, CH-1 equivalent, decay corrected to H + 48 hours. NA, not applicable. ND, gamma activity or mass not determined on sample. NSV, not a significant value. UCLA, activity at H + hours.

	Particle Size Range, Microns												
	2000 1000	1000 500	500 350	350 297	297 250	250 210	210 177	177 149	149 125	125 105	105 88	88 44	<44	Total
11.0 miles at 47° from GZ (12-6A)													
Mass, mg/ft^2	14.8	17.1	6.6	6.2	11.5	6.0	35.2	1.7	NSV	NSV	NSV	NSV	42.	141
Percent of mass	10.5	12.1	4.7	4.4	8.2	4.3	25.0	1.2	NSV	NSV	NSV	NSV	29.8	
Activity 10^3 $d/m/ft^2$ UCLA	1.8	1.0	NSV	NSV	NSV	1.6	12.0	NSV	NSV	NSV	NSV	NSV	38.7	58.2
Percent at H + 583 hrs	3.2	1.8	NSV	NSV	NSV	2.8	20.6	NSV	NSV	NSV	NSV	NSV	66.5	
10^6 $d/m/ft^2$ CH-1	0.11	0.06	NSV	NSV	NSV	0.10	0.71	NSV	NSV	NSV	NSV	NSV	2.28	3.43
10^5 d/m/mg	0.07	0.04	NSV	NSV	NSV	0.17	0.20	NSV	NSV	NSV	NSV	NSV	0.54	0.25
13.0 miles at 19° from GZ (12-13A)													
Mass, mg/ft^2	15.9	3.6	3.0	2.7	4.0	5.3	14.3	20.6	64.0	90.	101.	573.	1281.	2179.
Percent of mass	0.7	0.2	0.1	0.1	0.2	0.2	0.7	1.0	3.0	4.1	4.6	26.3	58.9	
Activity 10^3 $d/m/ft^2$ UCLA	193.	29.3	16.7	22.9	42.4	55.3	166.	218.	579	745.	936.	5530.	8620.	18570.
Percent at H + 585 hrs	1.04	0.16	0.09	0.12	0.23	0.30	0.89	1.17	3.12	4.01	5.04	29.8	46.4	
10^6 $d/m/ft^2$ CH-1	9.95	1.53	0.86	1.15	2.20	2.87	8.50	11.2	29.8	38.3	48.2	285.	443.	956.
10^5 d/m/mg	6.25	4.25	2.87	4.26	5.50	5.42	5.94	5.44	4.66	4.26	4.77	4.97	3.46	4.39
17.0 miles at 30° from GZ(20-2A)													
Mass, mg/ft^2	NSV	4.8	NSV	2.5	4.2	0.9	NSV	NSV	NSV	NSV	NSV	0.9	40.	53.3
Percent of mass	NSV	9.0	NSV	4.7	7.9	1.7	NSV	NSV	NSV	NSV	NSV	1.7	75.	
Activity 10^3 $d/m/ft^2$ UCLA	NSV	NSV	NSV	0.5	0.5	1.6	NSV	NSV	NSV	NSV	NSV	0.5	302.	316.
Percent at H + 343 hrs	NSV	NSV	NSV	0.15	0.17	0.50	NSV	NSV	NSV	NSV	NSV	0.15	95.6	
10^6 $d/m/ft^2$ CH-1	NSV	NSV	NSV	0.01	0.01	0.02	NSV	NSV	NSV	NSV	NSV	0.01	3.8	3.97
10^5 d/m/mg	NSV	NSV	NSV	0.02	0.02	0.22	NSV	NSV	NSV	NSV	NSV	0.07	0.95	0.75
17.5 miles at 27° from GZ (20-3B)													
Mass, mg/ft^2	12.0	5.4	3.1	1.3	4.1	2.6	121.	5.6	8.4	16.8	6.8	NSV	99.8	287.
Percent of mass	4.2	1.9	1.1	0.5	1.4	0.9	42.2	2.0	2.9	5.9	2.4	NSV	34.8	
Activity 10^3 $d/m/ft^2$ UCLA	5.6	2.0	NSV	NSV	2.4	1.2	67.	2.0	4.0	6.6	2.7	NSV	126.	242.
Percent at H + 600 hrs	2.31	0.83	NSV	NSV	0.99	0.50	27.6	0.83	1.65	2.73	1.11	NSV	52.1	
10^6 $d/m/ft^2$ CH-1	0.24	0.09	NSV	NSV	0.10	0.05	2.90	0.09	0.17	0.29	0.12	NSV	5.47	10.5
10^5 d/m/mg	0.20	0.17	NSV	NSV	0.25	0.19	0.24	0.16	0.20	0.17	0.18	NSV	0.55	0.37

Table A.2 GAMMA ACTIVITY AND MASS DISTRIBUTION ACCORDING TO PARTICLE SIZE (CONTINUED)

	Particle Size Range, Microns													
	2000 1000	1000 500	500 350	350 297	297 250	250 210	210 177	177 149	149 125	125 105	105 88	88 44	<44	Total
18.2 miles at 24° from GZ (20-4A)														
Mass, mg/ft^2	38.1	33.6	14.7	5.5	11.5	11.4	11.7	16.5	22.4	11.9	27.7	98.4	44.9	348
Percent of mass	10.9	9.7	4.2	1.6	3.3	3.3	3.4	4.7	6.4	3.4	8.0	28.3	12.9	
Activity 10^3 d/m/ft^{2}UCLA	NSV	0.9	NSV	0.7	NSV	NSV	NSV	2.1	2.3	4.4	20.5	282.	1049.	1405
Percent at H + 340 hrs	NSV	0.06	NSV	0.05	NSV	NSV	NSV	0.15	0.16	0.31	1.50	20.1	74.6	
10^6 d/m/ft^2 CH-1	NSV	0.002	NSV	0.002	NSV	NSV	NSV	0.05	0.05	0.10	0.47	6.3	23.5	31.5
10^5 d/m/mg	NSV	0.001	NSV	0.003	NSV	NSV	NSV	0.03	0.02	0.08	0.17	0.64	5.23	0.91
36.4 miles at 29° from GZ (32-6A)														
Mass, mg/ft^2	21.6	7.6	3.8	NSV	2.4	1.0	2.5	1.5	2.00	1.0	3.7	11.9	48.1	107
Percent of mass	20.2	7.1	3.5	NSV	2.2	0.9	2.3	1.4	1.9	0.9	3.5	11.1	45.0	
Activity 10^3 d/m/ft^{2}UCLA	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	3.35	24.5	30.4
Percent at H + 602 hrs	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	11.0	80.5	
10^6 d/m/ft^2 CH-1	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.23	1.67	2.08
10^5 d/m/mg	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.19	0.35	0.19
32.6 miles at 20° from GZ (32-13A)														
Mass, mg/ft^2	8.8	18.0	16.8	7.1	14.0	15.5	16.8	23.0	32.3	23.0	37.7	74.3	77.0	364
Percent of mass	2.4	5.0	4.6	2.0	3.8	4.3	4.6	6.3	8.9	6.3	10.3	20.4	21.1	
Activity 10^3 d/m/ft^{2}UCLA	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	6.1	133.	529.	668
Percent at H + 409 hrs	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.9	19.9	79.2	
10^6 d/m/ft^2 CH-1	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.20	4.46	17.7	22.4
10^5 d/m/mg	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.05	0.60	2.30	0.62
31.2 miles at 15° from GZ (32-16B)														
Mass, mg/ft^2	13.9	38.6	23.1	25.8	26.6	26.0	49.0	32.1	47.0	45.0	53.7	211.	433.	1027
Percent of mass	1.4	3.8	2.3	2.5	2.6	2.5	4.8	3.1	4.6	4.4	5.2	20.5	42.1	
Activity 10^3 d/m/ft^{2}UCLA	52.6	12.7	5.2	8.5	7.7	5.4	138.	55.0	124.	165.	240.	1230.	3370.	5936
Percent at H + 601 hrs	0.89	0.21	0.09	0.14	0.13	0.09	2.33	0.93	2.09	2.78	4.04	20.7	56.8	
10^6 d/m/ft^2 CH-1	2.6	0.6	0.3	0.4	0.4	0.3	6.9	2.7	6.2	8.2	11.9	61.0	167.5	295
10^5 d/m/mg	1.89	0.16	0.12	0.16	0.14	0.10	1.40	0.85	1.31	1.82	2.22	2.89	3.87	2.87

Table A. 2 GAMMA ACTIVITY AND MASS DISTRIBUTION ACCORDING TO PARTICLE SIZE (CONTINUED)

	Particle Size Range, Microns													
	2000 1000	1000 500	500 350	350 297	297 250	250 210	210 177	177 149	149 125	125 105	105 88	88 44	<44	Total
30.8 miles at 13° from GZ (32-17B)														
Mass, mg/ft^2	15.0	6.0	10.	11.	4.0	3.0	40.	39.	18.	91.	84.	394.	624.	1339
Percent of mass	1.1	0.5	0.8	0.8	0.3	0.2	3.0	2.9	1.3	6.8	6.3	29.4	46.6	
Activity 10^3 d/m/ft^2 UCLA	76.7	22.3	4.0	2.6	32.3	20.9	171.	43.	44.	400.	550.	2980.	6440.	12347
Percent at H + 603 hrs	0.62	0.18	0.03	0.02	0.26	0.17	1.38	0.35	0.36	3.24	4.45	24.1	52.2	
10^6 d/m/ft^2 CH-1	4.3	1.2	0.21	0.14	1.79	1.17	9.5	2.41	2.48	22.3	30.7	166.	359.7	689
10^5 d/m/mg	2.87	2.07	0.21	0.13	4.48	3.90	2.38	0.62	1.38	2.45	3.65	4.21	5.76	5.14
42.5 miles at 25° from GZ (50-7A)														
Mass, mg/ft^2	21.9	17.5	4.9	6.3	8.6	12.6	43.8	35.9	36.9	5.0	30.3	31.4	30.4	286
Percent of mass	7.6	6.1	1.7	2.2	3.0	4.4	15.3	12.5	12.9	1.7	10.6	11.0	10.6	
Activity 10^3 d/m/ft^2 UCLA	12.8	12.6	3.4	2.5	3.9	6.7	11.9	12.1	6.6	?	3.7	18.0	135.	252
Percent at H + 244 hrs	5.1	5.0	1.4	1.0	1.5	2.6	4.7	4.8	2.6	?	1.5	7.2	53.6	
10^6 d/m/ft^2 CH-1	0.23	0.23	0.06	0.04	0.07	0.12	0.22	0.22	0.12	?	0.07	0.33	2.47	4.61
10^5 d/m/mg	0.11	0.13	0.12	0.06	0,08	0.10	0.05	0.06	0.03	?	0.02	0.11	0.81	0.16
47.5 miles at 25° from GZ (50-12A)														
Mass, mg/ft^2	6.7	15.6	4.7	1.2	3.9	4.2	3.7	7.7	12.8	10.0	25.1	81.	35.3	212
Percent of mass	3.2	7.4	2.2	0.6	1.8	2.0	1.7	3.6	6.0	4.7	11.8	38.2	16.7	
Activity 10^3 d/m/ft^2 UCLA	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.96	23.8	185.	228.
Percent at H + 272 hrs	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.42	10.4	81.0	
10^6 d/m/ft^2 CH-1	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.02	0.47	3.64	4.50
10^5 d/m/mg	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.01	0.06	1.03	0.21
49.2 miles at 22° from GZ (50-15A)														
Mass, mg/ft^2	6.7	8.6	9.2	7.0	12.3	10.4	9.5	19.5	23.0	17.1	39.9	70.4	72.1	306
Percent of mass	2.2	2.8	3.0	2.3	4.0	3.4	3.1	6.4	7.5	5.6	13.0	23.0	23.6	
Activity 10^3 d/m/ft^2 UCLA	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	1.3	24.4	278.	317
Percent at H + 316 hrs	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.42	7.7	87.7	
10^6 d/m/ft^2 CH-1	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.03	0.56	6.35	7.24
10^5 d/m/mg	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.01	0.08	0.88	0.24

Table A.2 GAMMA ACTIVITY AND MASS DISTRIBUTION ACCORDING TO PARTICLE SIZE (CONTINUED)

	Particle Size Range, Microns													
	2000 1000	1000 500	500 350	350 297	297 250	250 210	210 177	177 149	149 125	125 105	105 88	88 44	<44	Total
50.5 miles at 21° from GZ (50-17A)														
Mass, mg/ft^2	2.5	4.2	5.6	3.6	8.6	10.7	14.2	20.7	25.9	15.8	26.4	70.5	49.4	258
Percent of mass	1.0	1.6	2.2	1.4	3.3	4.1	5.5	8.0	10.0	6.1	10.2	27.3	19.1	
Activity 10^3 d/m/ft^2 UCLA	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	2.61	71.5	468.	583
Percent at H + 244 hrs	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.45	12.3	80.4	
10^6 d/m/ft^2 CH-1	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.04	1.02	6.7	8.33
10^5 d/m/mg	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.01	0.15	1.35	0.32
51.5 miles at 20° from GZ (50-18B)														
Mass, mg/ft^2	9.0	9.9	5.4	1.8	6.2	8.5	13.5	20.1	40.2	22.9	45.5	98.5	65.9	347
Percent of mass	2.6	2.9	1.6	0.5	1.8	2.4	3.9	5.8	11.6	6.6	13.1	28.4	19.0	
Activity 10^3 d/m/ft^2 UCLA	NSV	NSV	NSV	NSV	NSV	NSV	0.9	NSV	1.2	1.1	3.7	101.	552.	674
Percent at H + 288 hrs	NSV	NSV	NSV	NSV	NSV	NSV	0.13	NSV	0.17	0.16	0.55	15.0	82.0	
10^6 d/m/ft^2 CH-1	NSV	NSV	NSV	NSV	NSV	NSV	0.01	NSV	0.01	0.01	0.04	1.15	6.29	7.68
10^5 d/m/mg	NSV	NSV	NSV	NSV	NSV	NSV	0.01	NSV	0.003	0.01	0.01	0.12	0.95	0.22
71.0 miles at 26° from GZ (70-5B)														
Mass, mg/ft^2	3.7	2.6	NSV	NSV	NSV	2.6	3.0	NSV	NSV	NSV	NSV	NSV	5.7	18
Percent of mass	21.0	14.8	NSV	NSV	NSV	14.8	17.0	NSV	NSV	NSV	NSV	NSV	32.4	
Activity 10^3 d/m/ft^2 UCLA	58.	69.2	5.9	4.0	6.9	11.1	57.5	5.5	3.9	3.8	-	1.8	1650.	1995
Percent at H + 129 hours	2.9	3.5	0.3	0.2	0.4	0.6	2.9	0.3	0.2	0.2	-	0.1	82.7	
10^6 d/m/ft^2 CH-1	0.39	0.47	0.04	0.03	0.05	0.08	0.39	0.04	0.03	0.03	-	0.01	11.15	13.5
10^5 d/m/mg	1.05	1.81	NSV	NSV	NSV	0.31	1.30	NSV	NSV	NSV	-	NSV	1.96	7.50
70.5 miles at 28° from GZ (70-8A)														
Mass, mg/ft^2	4.6	4.3	1.2	NSV	NSV	NSV	NSV	NSV	NSV	NSV	2.0	8.7	53.8	75
Percent of mass	6.1	5.7	1.6	NSV	NSV	NSV	NSV	NSV	NSV	NSV	2.7	11.6	72.1	
Activity 10^3 d/m/ft^2 UCLA	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	3.1	122.	130
Percent at H + 432 hrs	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	2.4	93.8	
10^6 d/m/ft^2 CH-1	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.10	3.76	4.01
10^5 d/m/mg	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	NSV	0.11	0.70	0.54

TABLE A. 2 GAMMA ACTIVITY AND MASS DISTRIBUTION ACCORDING TO PARTICLE SIZE (CONTINUED)

	Particle Size Range, Microns												
	2000 1000	1000 500	500 350	350 297	297 250	250 210	210 177	177 149	149 125	125 105	105 88	88 44	<44	Total
70.5 miles at 29° from GZ (70-9A)														
Mass, mg/ft^2	47.3	21.4	27.2	3.1	3.3	3.2	12.9	5.6	8.9	9.0	6.5	23.1	84.6	256
Percent of mass	18.5	8.4	10.6	1.2	1.3	1.3	5.0	2.2	3.5	3.5	2.5	9.0	33.0	
Activity 10^3 d/m/ft^2 UCLA	11.0	6.8	2.0	1.8	2.7	1.0	6.9	3.7	2.7	5.0	1.1	14.3	409.	474
Percent at H + 146 hrs	2.3	1.5	0.42	0.38	0.57	0.21	1.5	0.78	0.57	1.05	0.23	3.0	86.3	
10^6 d/m/ft^2 CH-1	0.06	0.04	0.01	0.01	0.02	0.01	0.04	0.02	0.02	0.03	0.01	0.08	2.33	2.70
10^5 d/m/mg	0.01	0.02	0.004	0.03	0.06	0.02	0.03	0.04	0.02	0.03	0.01	0.04	0.28	0.11
70.0 miles at 30° from GZ (70-10A)														
Mass, mg/ft^2	9.2	6.4	2.8	2.7	3.1	3.1	14.0	4.2	4.9	5.1	NSV	2.1	46.4	104
Percent of mass	8.9	6.1	2.7	2.6	3.0	3.0	13.5	4.0	4.7	4.9	NSV	2.0	44.6	
Activity 10^3 d/m/ft^2 UCLA	8.0	5.5	1.8	1.6	1.8	3.7	7.2	3.0	2.9	4.4	NSV	1.3	344.	395
Percent at H + 146 hrs	2.0	1.4	0.44	0.39	0.46	0.94	1.8	0.76	0.73	1.1	NSV	0.33	87.1	
10^6 d/m/ft^2 CH-1	0.05	0.03	0.01	0.01	0.01	0.02	0.04	0.02	0.02	0.03	NSV	0.01	2.07	2.38
10^5 d/m/mg	0.05	0.05	0.04	0.03	0.04	0.07	0.03	0.04	0.04	0.05	NSV	0.04	0.45	0.23
70.5 miles at 33° from GZ (70-15A)														
Mass, mg/ft^2	7.1	3.3	NSV	NSV	NSV	NSV	3.7	NSV	NSV	NSV	NSV	NSV	28.0	42
Percent of mass	16.9	7.9	NSV	NSV	NSV	NSV	8.8	NSV	NSV	NSV	NSV	NSV	66.6	
Activity 10^3 d/m/ft^2 UCLA	1.9	1.0	NSV	NSV	NSV	NSV	1.0	NSV	NSV	NSV	NSV	NSV	34.4	40
Percent at H + 584 hrs	4.7	2.4	NSV	NSV	NSV	NSV	2.5	NSV	NSV	NSV	NSV	NSV	86.0	
10^6 d/m/ft^2 CH-1	0.08	0.04	NSV	NSV	NSV	NSV	0.04	NSV	NSV	NSV	NSV	NSV	1.39	1.62
10^5 d/m/mg	0.11	0.12	NSV	NSV	NSV	NSV	0.11	NSV	NSV	NSV	NSV	NSV	0.50	0.39
69.0 miles at 35° from GZ (70-18A)														
Mass, mg/ft^2	7.3	1.8	NSV	NSV	NSV	NSV	2.7	NSV	NSV	NSV	NSV	NSV	21.7	34
Percent of mass	21.5	5.3	NSV	NSV	NSV	NSV	7.9	NSV	NSV	NSV	NSV	NSV	63.8	
Activity 10^3 d/m/ft^2 UCLA	7.8	5.1	NSV	NSV	NSV	NSV	3.4	NSV	NSV	NSV	NSV	NSV	226.	251
Percent at H + 148 hrs	3.1	2.0	NSV	NSV	NSV	NSV	1.3	NSV	NSV	NSV	NSV	NSV	90.0	
10^6 d/m/ft^2 CH-1	0.05	0.04	NSV	NSV	NSV	NSV	0.02	NSV	NSV	NSV	NSV	NSV	1.6	1.73
10^5 d/m/mg	0.07	0.19	NSV	NSV	NSV	NSV	0.08	NSV	NSV	NSV	NSV	NSV	0.72	0.51

Table A.3 RADIOACTIVITY PER UNIT AREA AND PER UNIT MASS

Activity expressed in CH-1 equivalent units corrected to H + 48 hours

Station Number	Radioactivity per Unit Area $10^6 d/m/ft^2$	Radioactivity per Unit Mass $10^5 d/m/mg$
12- 1	750	4.96
12- 2	6.42	-
12- 4	3.11	-
12- 5	1.24	-
12- 6	3.43	0.25
12- 8	0.76	-
12-10	10005	-
12-11	5430	4.27
12-12	4200	-
12-13	985	4.68
12-14	331	3.52
12-15	26.5	-
20- 1	3.53	-
20- 2	3.99	-
20- 3	9.43	0.33
20- 4	35.1	0.89
20- 5	40.7	-
20- 6	66.1	-
20- 7	125	3.29
20- 8	420	-
20- 9	756	-
20-10	1130	4.48
20-11	1345	4.95
20-12	1700	5.17
20-13	1770	4.55
32- 2	1.12	-
32- 3	1.03	-
32- 4	1.36	-
32- 5	1.33	-
32- 6	1.99	0.18
32- 7	2.83	-
32- 8	3.26	-
32- 9	3.85	-
32-10	4.92	0.26
32-11	6.22	-
32-12	9.37	0.39
32-13	22.0	0.58
32-14	77.6	0.27
32-15	46.2	2.06
32-16	280	2.73
32-17	696	5.10
32-18	600	4.80
32-19	1265	5.52
32-20	1810	-

Table A.3 RADIOACTIVITY PER UNIT AREA AND PER UNIT MASS (CONTINUED)

Station Number	Radioactivity per Unit Area 10^6d/m/ft^2	Radioactivity per Unit Mass 10^5d/m/mg
50- 1	2.38	-
50- 2	2.51	0.19
50- 3	2.68	0.15
50- 4	2.98	-
50- 5	3.56	-
50- 6	4.14	-
50- 7	5.06	0.14
50- 9	4.81	-
50-10	4.69	-
50-11	4.17	-
50-12	4.27	-
50-13	4.55	-
50-14	4.86	-
50-15	6.90	0.22
50-16	9.00	-
50-17	8.44	0.33
50-18	11.2	0.30
50-19	15.7	-
50-20	17.3	0.41
60- 1	15.0	0.67
60- 2	14.8	1.09
60- 3	14.6	-
70- 1	16.2	-
70- 2	14.0	-
70- 3	13.9	-
70- 4	12.0	4.00
70- 5	12.3	6.48
70- 6	9.52	-
70- 7	5.90	1.31
70- 8	4.62	-
70- 9	3.15	0.13
70-10	2.91	0.26
70-12	3.25	0.96
70-14	2.67	-
70-16	1.79	0.53
70-17	2.39	-
70-18	2.05	0.54
70-19	1.93	-
70-20	1.68	-

Table A.4 RADIOACTIVITY REMAINING ON PELLETS

Percent of activity determined at time of counting

Station Number	Activity on Pellet Matrix, Percent	Total Activity 10^5 d/m/sample
12- 1A	12.05	666
12- 4B	12.90	4.79
12- 6AB	7.99	8.13
12-13AB	7.98	1750
12-14B	11.00	290
Mean Value	9.57 $\pm$ 2.83	
20- 2A	3.25	42.76
20- 3B	10.15	13.00
20- 4AB	4.08	231
20-11B	4.25	1550
20-12B	3.35	1760
Mean Value	6.15 $\pm$ 3.43	
32- 6A	8.16	10.79
32- 7B	8.28	4.22
32-10A	4.33	31.41
32-12A	8.11	62.90
32-13A	-	112
32-14AB	1.78	550
32-16B	10.30	308
32-17B	10.05	600
32-18B	10.06	636
Mean Value	8.81 $\pm$ 2.18	

Table A.4 RADIOACTIVITY REMAINING ON PELLETS (CONTINUED)

Station Number	Activity on Pellet Matrix, Percent	Total Activity 10^5 d/m/sample
50- 4A	6.64	24.10
50- 6B	11.70	6.59
50- 7AB	6.12	45.43
50- 8A	17.10	34.96
50-12A	7.39	37.04
50-15A	3.80	63.51
50-17A	6.48	79.50
50-18B	4.63	122.3
Mean Value	8.84 $\pm$ 5.28	
60- 3A	9.84	116.2
70- 3AB	6.56	54.58
70- 5B	5.52	132.3
70- 7A	2.74	72.99
70- 8A	3.79	42.89
70- 9A	1.31	35.77
70-10A	2.60	29.63
70-12A	3.42	23.72
70-14A	7.55	12.06
70-15A	4.11	18.75
70-18A	3.23	18.57
Mean Value	4.32 $\pm$ 2.48	

Table A.5 CLOUD PASSAGE AND FALLOUT RADIATION MEASUREMENTS

Station Number	Area sq cm	One sq cm equals, mr	Dose,mr	Total Dose, mr	Percent of Total Dose
12- 1					
Cloud	11.0	500	5500		
	32.0	25	800	6300	76.8
Fallout	0.5	500	250		
	66.0	25	1650	1900	23.2
20- 9					
Cloud	20.00	25	500	500	36.8
Fallout	34.8	25	860	860	63.2
32-15					
Cloud	9.5	10.	95.		
	1.9	2.5	4.75	99.75	38.6
Fallout	2.6	10.	26.		
	53.0	2.5	132.5	158.5	61.4
50-15					
Cloud	15.0	0.125	1.9	1.9	18.6
Fallout	66.0	0.125	8.3	8.3	81.4
60- 3					
Cloud	33.0	0.25	8.25	8.25	45.1
Fallout	40.0	0.25	10.0	10.0	54.9
50-10					
Cloud	172.0	0.025	43.0	43.0	100.0

Table A.6 GAMMA DECAY DATA OBTAINED ON THE CH-1 COUNTER

Samples were counted on the fifth shelf of the CH-1 counter

12-10B		20-13B		32-20B		50-20B		70-1A	
H + hr	c/m/sample	H + hr	c/m/sample	H + hr	c/m/sample	H + hr	c/m/sample	H + hr	c/m/sample
48.5	2,933,600	51.8	593,682	53.5	523,513	49.4	5838	52.5	5171
54.4	2.754,208	54.3	563,144	54.2	530,498	54.1	5336	54.0	5413
70.6	2,170,298	70.7	392,045	70.8	376,826	70.8	4043	70.8	3480
-	-	78.9	335,030	79.0	314,013	79.1	2969	79.4	2992
94.8	1,509,621	94.9	255,442	95.0	239,968	95.1	2225	95.2	2219
102.8	1,382,264	102.9	217,523	103.0	204,518	103.0	2064	103.2	2032
121.6	1,069,000	121.6	170,300	121.7	159,066	121.8	1533	121.9	1515
144.4	818,670	144.9	127,671	145.1	121,170	145.2	1504	145.3	1529
153.4	757,163	153.5	118,227	153.7	111,125	153.6	1409	153.9	1265
165.3	684,665	165.7	106,454	165.8	97,274	165.9	1238	166.1	950
177.5	616,107	178.0	93,857	178.0	87,807	178.0	1116	178.0	868
219.0	473,540	219.0	71,129	219.0	66,560	219.0	1192	219.0	1194
238.0	418,844	238.0	62,331	238.0	58,355	238.0	-	-	-
360.0	247,523	360.0	38,880	360.0	35,404	360.0	380	360.0	396
406.0	223,386	406.0	34,570	406.0	31,550	406.0	315	406.0	305

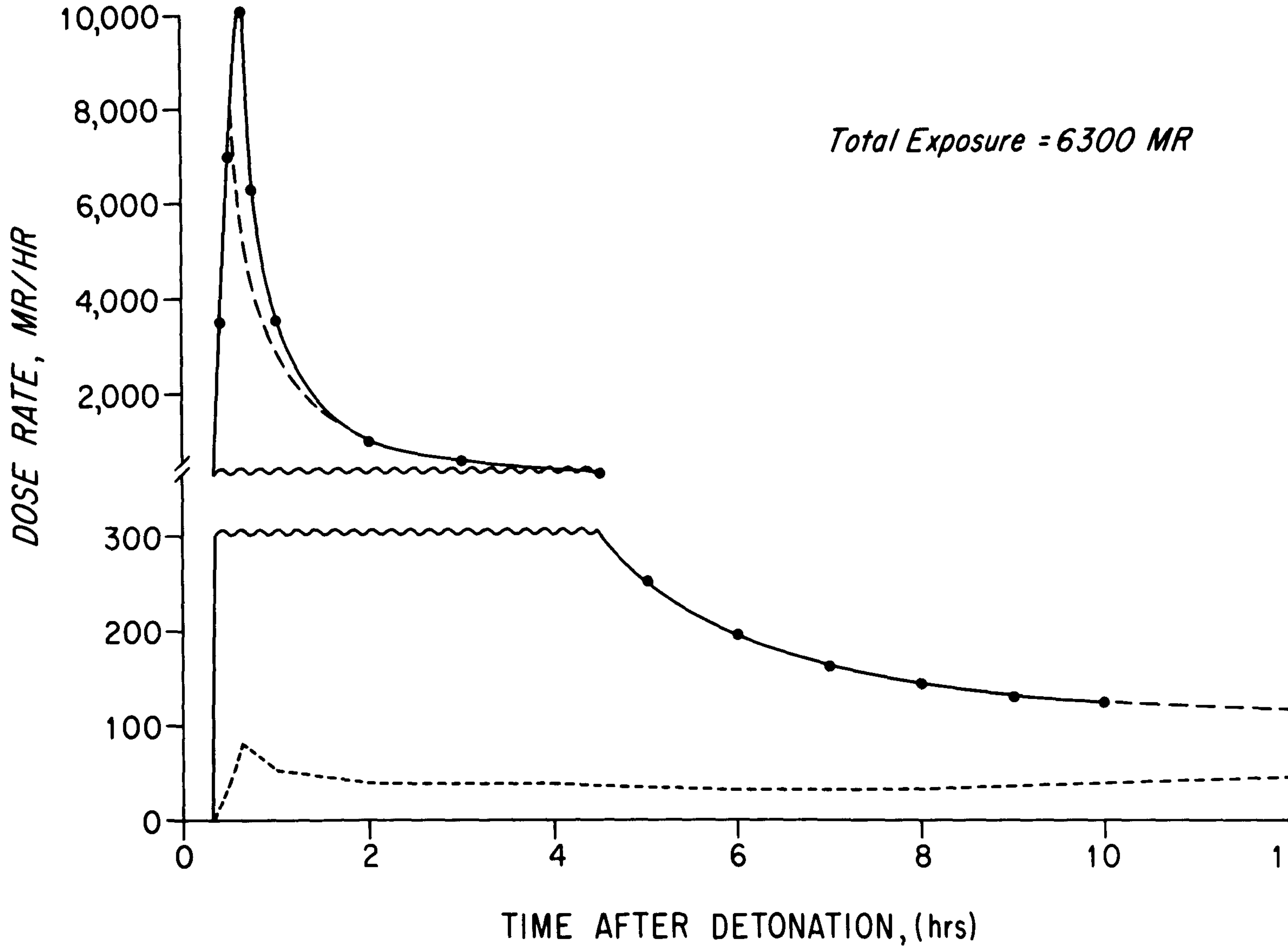

FIGURE A.1 TOTAL INTEGRATED DOSE DUE TO CLOUD PASSAGE AT STATION 12-1

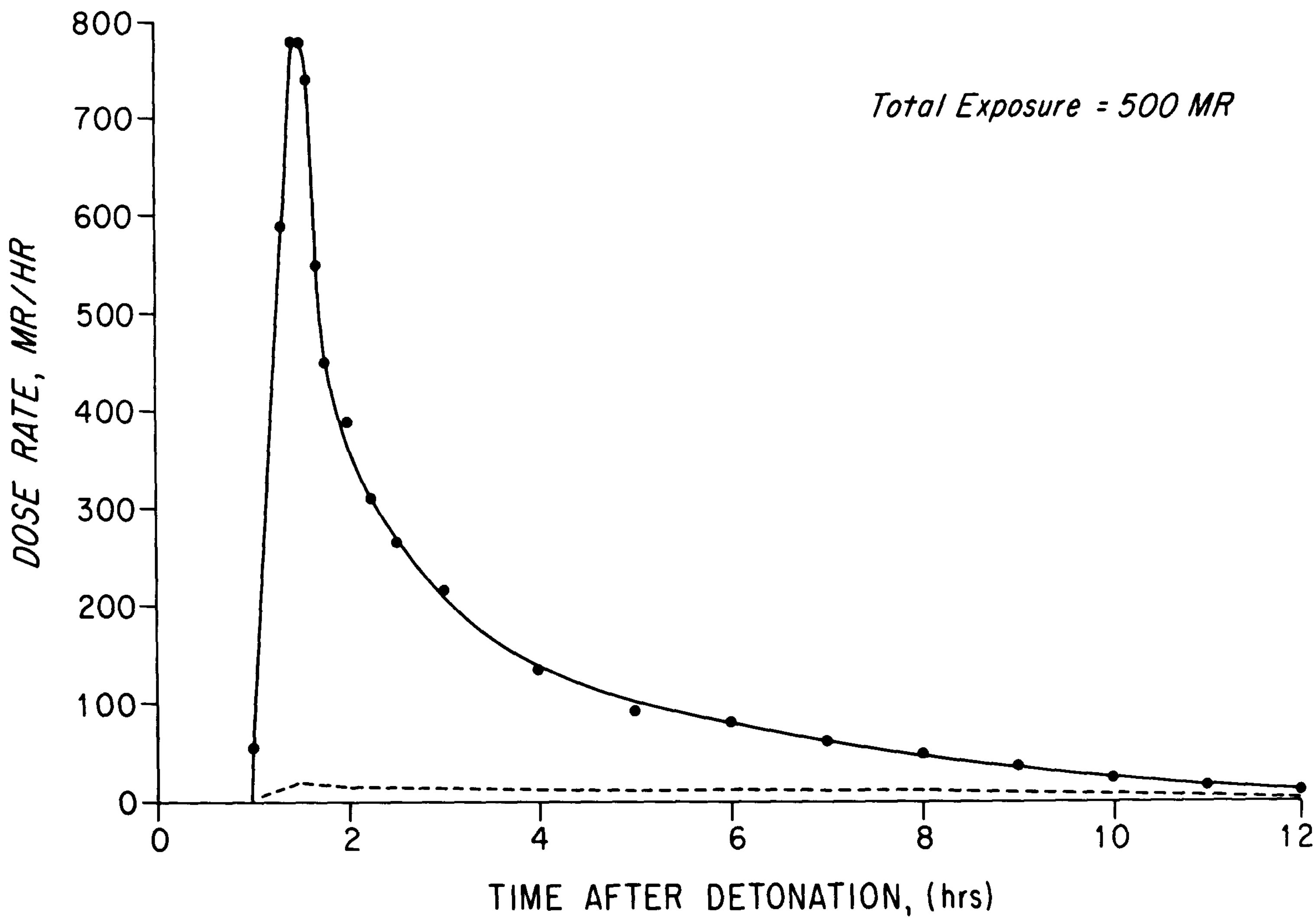

FIGURE A. 2 TOTAL INTEGRATED DOSE DUE TO CLOUD PASSAGE AT STATION 20-9

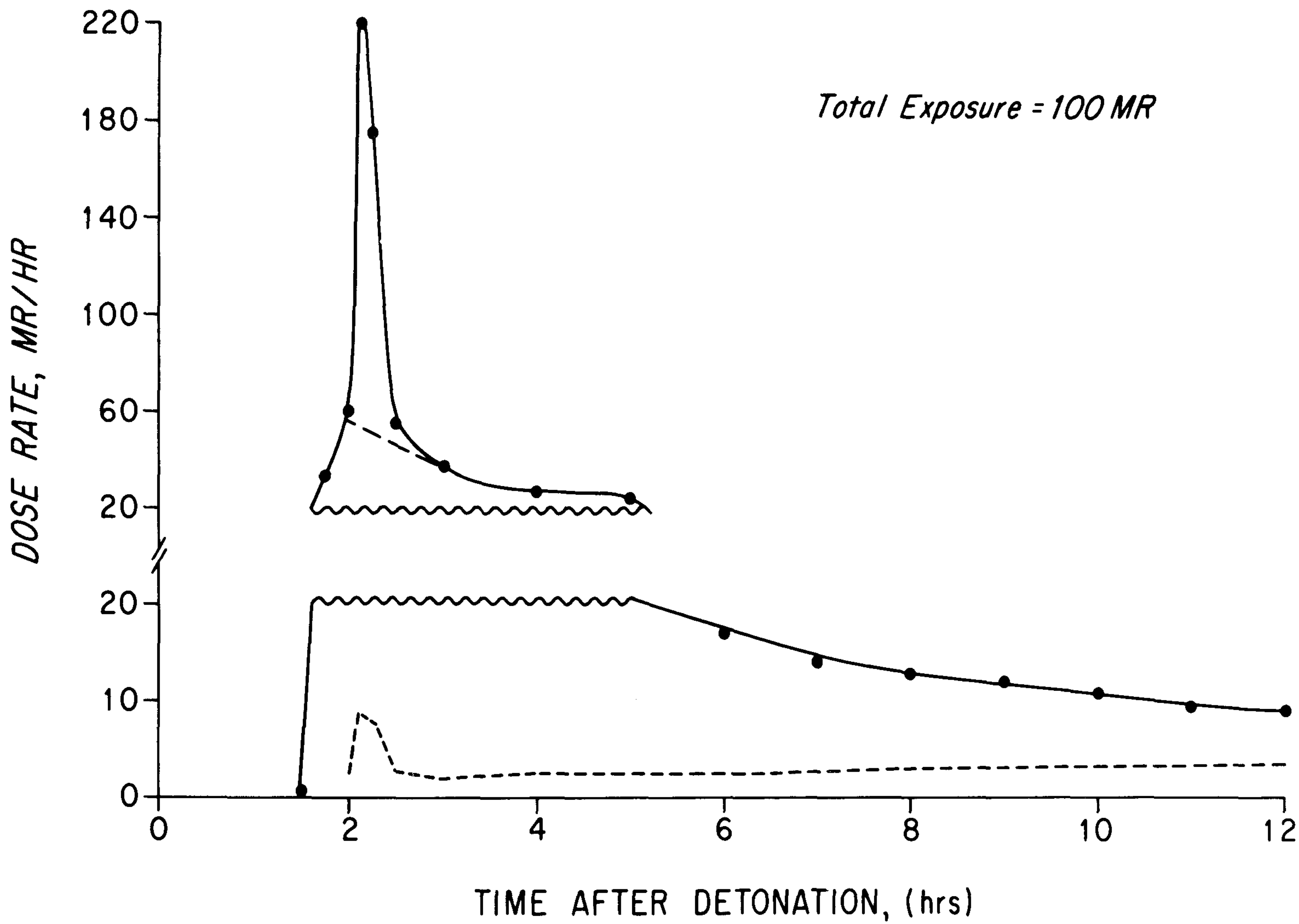

FIGURE A.3 TOTAL INTEGRATED DOSE DUE TO CLOUD PASSAGE AT STATION 32-15

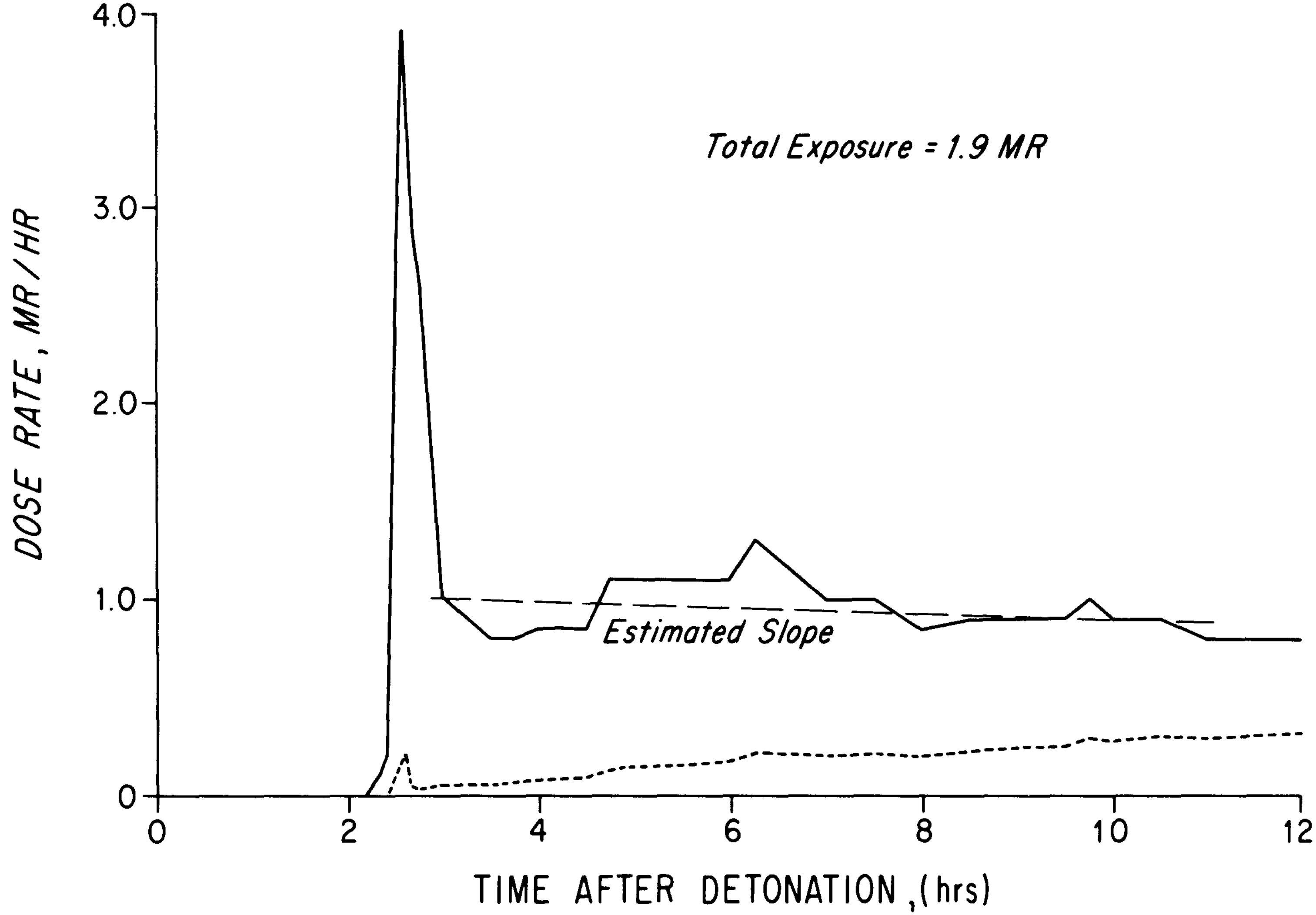

FIGURE A.4 TOTAL INTEGRATED DOSE DUE TO CLOUD PASSAGE AT STATION 50-15

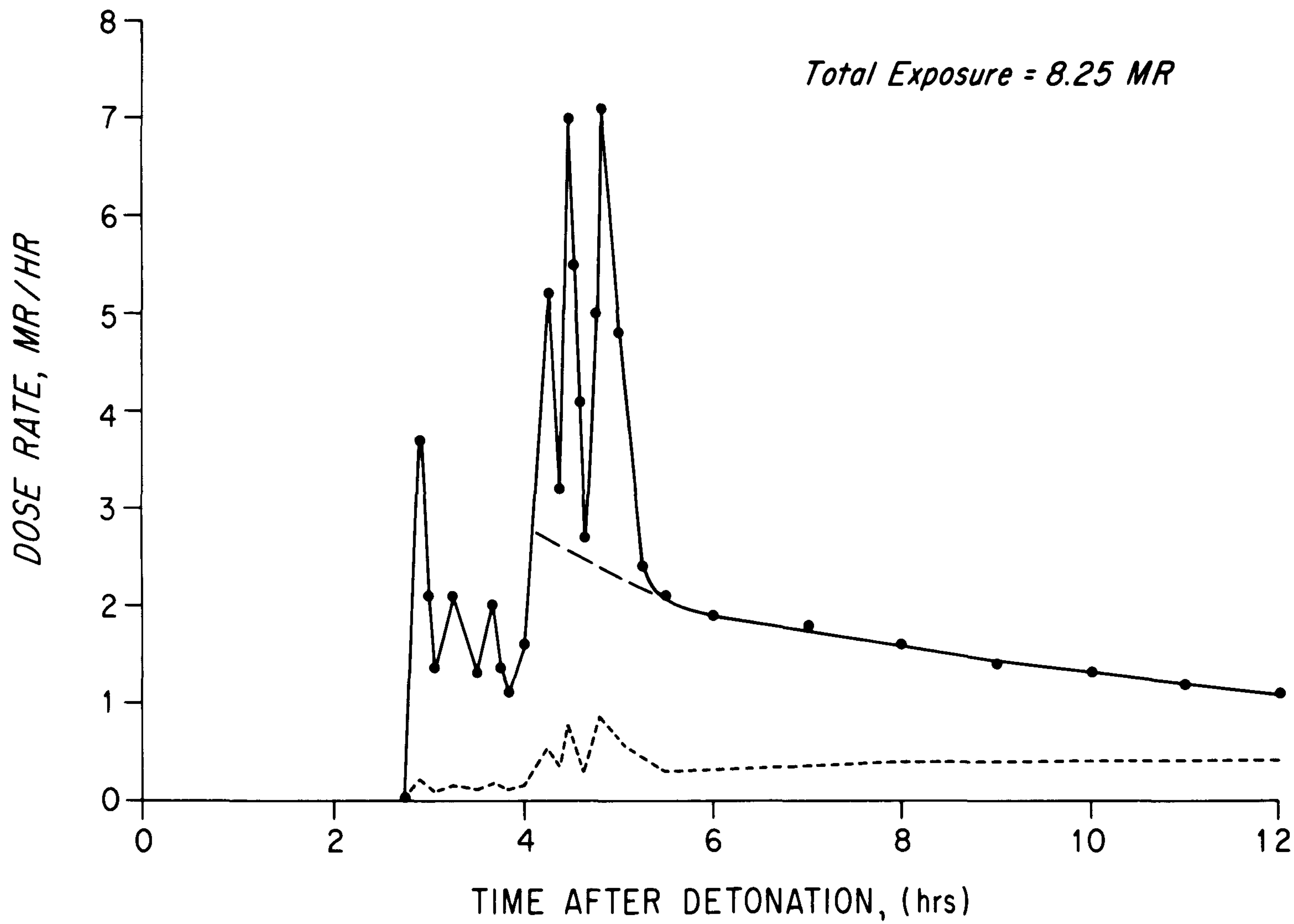

FIGURE A.5 TOTAL INTEGRATED DOSE DUE TO CLOUD PASSAGE AT STATION 60-3

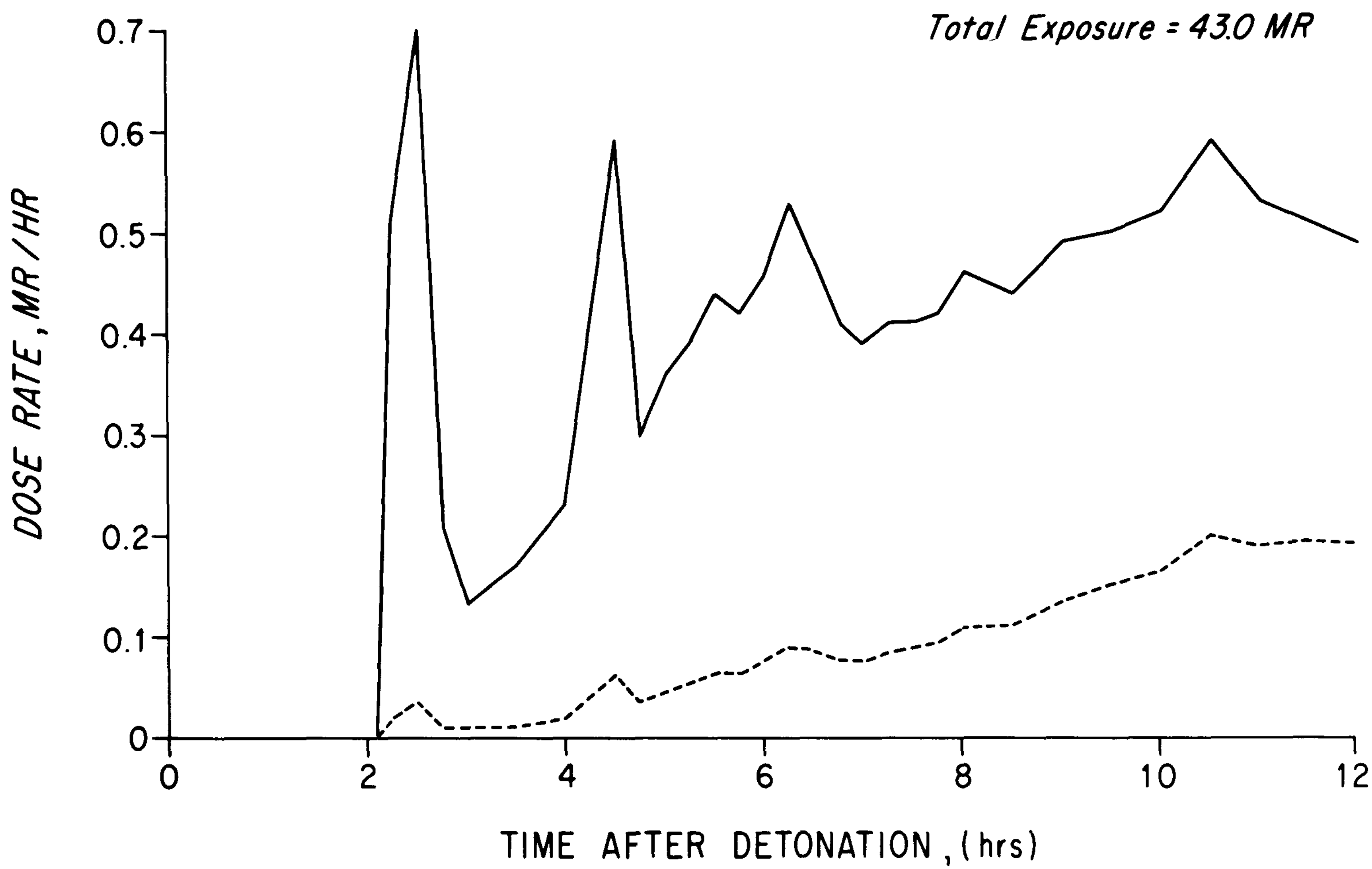

FIGURE A. 6 TOTAL INTEGRATED DOSE DUE TO CLOUD PASSAGE AT STATION 50-10

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TECHNICAL REPORTS SCHEDULED FOR ISSUANCE
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AEC REPORTS

AGENCY	PNE NO.	SUBJECT OR TITLE
USPHS	200F	Off-Site Radiation Safety
USWB	201F	Analysis of Weather and Surface Radiation Data
SC	202F	Long Range Blast Propagation
REECO	203F	On-Site Rad-Safe
AEC/USBM	204F	Structural Survey of Private Mining Operations
FAA	205F	Airspace Closure
SC	211F	Close-In Air Blast From a Nuclear Event in NTS Desert Alluvium
LRL-N	212P	Scientific Photo
LRL	214P	Fallout Studies
LRL	215F	Structure Response
LRL	216P	Crater Measurements
Boeing	217P	Ejecta Studies
LRL	218P	Radioactive Pellets
USGS	219F	Hydrologic Effects, Distance Coefficients
USGS	221P	Infiltration Rates Pre and Post Shot
UCLA	224P	Influences of a Cratering Device on Close-In Populations of Lizards
UCLA	225P Pt. I and II	Fallout Characteristics

TECHNICAL REPORTS SCHEDULED FOR ISSUANCE BY AGENCIES PARTICIPATING IN PROJECT SEDAN

AGENCY	PNE NO.	SUBJECT OR TITLE
BYU	226P	Close-In Effects of a Subsurface Nuclear Detonation on Small Mammals and Selected Invertabrates
UCLA	228P	Ecological Effects
LRL	231F	Rad-Chem Analysis
LRL	232P	Yield Measurements
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ABBREVIATIONS FOR TECHNICAL AGENCIES

STL	Space Technology Laboratories, Inc., Redondo Beach, Calif.
SC	Sandia Corporation, Sandia Base, Albuquerque, New Mexico
USC&GS	U. S. Coast and Geodetic Survey, San Francisco, California
LRL	Lawrence Radiation Laboratory, Livermore, California
LRL-N	Lawrence Radiation Laboratory, Mercury, Nevada
Boeing	The Boeing Company, Aero-Space Division, Seattle 24, Washington
USGS	Geological Survey, Denver, Colorado, Menlo Park, Calif., and Vicksburg, Mississippi
WES	USA Corps of Engineers, Waterways Experiment Station, Jackson, Mississippi
EGG	Edgerton, Germeshausen, and Grier, Inc., Las Vegas, Nevada, Santa Barbara, Calif., and Boston, Massachusetts
BYU	Brigham Young University, Provo, Utah
UCLA	UCLA School of Medicine, Dept. of Biophysics and Nuclear Medicine, Los Angeles, Calif.
NRDL	Naval Radiological Defense Laboratory, Hunters Point, Calif.
USPHS	U. S. Public Health Service, Las Vegas, Nevada
USWB	U. S. Weather Bureau, Las Vegas, Nevada
USBM	U. S. Bureau of Mines, Washington, D. C.
FAA	Federal Aviation Agency, Salt Lake City, Utah
REECO	Reynolds Electrical and Engineering Co., Las Vegas, Nevada

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